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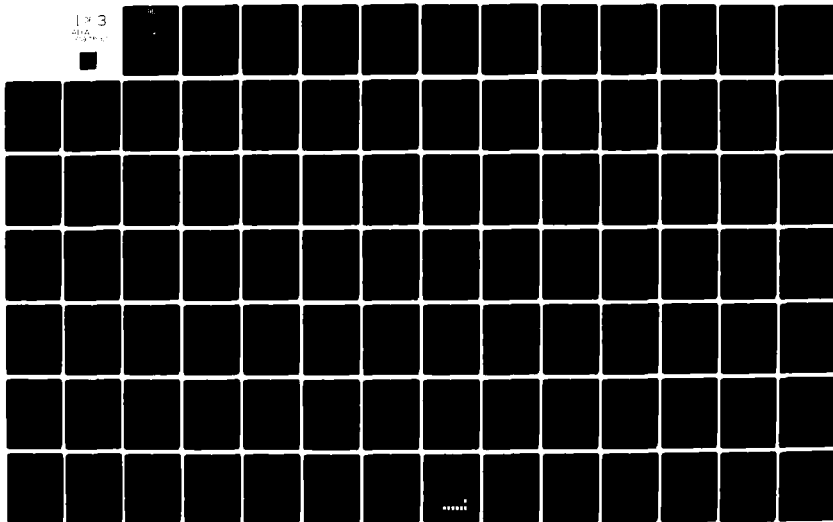
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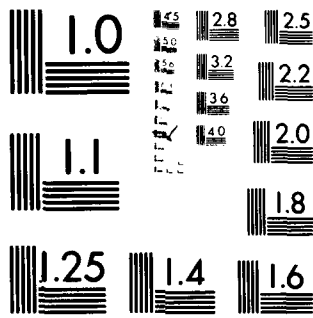
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SIGNAL SELECTOR, SPECTRUM RECEIVERS
AND TOUCH PANEL CONTROL FOR THE
SATCOM SIGNAL ANALYZER

Davis R. Gamble, Jr.
John E. Ohlson

June 1980

Technical Report

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The menu concept of operation provides the operator-hardware interface. A menu is a video display of information and a series of buttons presented to the operator on the Hewlett-Packard (HP) 2649A Display Terminal. This report examines the menu concept from source file to display on the operator's console and backup display on the CONRAC QQA-17 large screen video monitor.

ABSTRACT

This report documents the design, development, construction, and integration of two major modules and the software interface between the operator and the hardware of the SATCOM Signal Analyzer (SSA). The two modules are the Signal Selector and the Spectrum Receiver.

Each SSA contains one Signal Selector which is the system's computer controlled switching network. Laboratory test procedures and results are contained in this report.

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I. SATCOM SIGNAL ANALYZER (SSA)

A. BACKGROUND

The Satellite Communications Laboratory of the Naval Postgraduate School is developing the prototype SATCOM Signal Analyzer (SSA). The project is sponsored by NAVELEX PNE-106-1. Naval Communication Area Master Stations (NAVCAMS) and Naval Communications Stations (NAVCOMMS-TAs) around the world are using the Fleet Satellite Monitoring (FSM) system to perform satellite monitoring functions. Because of many state of the art developments in recent years, the capabilities of the FSM are somewhat outdated. Digital sampling techniques have begun a new trend in spectral analysis. The SSA takes advantage of state-of-the-art digital techniques for its high-speed real-time spectral analysis capability. It also uses a minicomputer to control the operation of the hardware and interface with the operator.

The SSA provides real-time multi-channel analysis of satellite downlink signals and local uplink signals as well as delayed analysis by use of the tape playback feature. Real-time analysis includes the capability to observe the frequency spectrum with one of four intermediate frequency (IF) bandwidths, monitor the time domain presentation of a selected signal on an oscilloscope, aurally monitor the demodulated signal, view PSK signals on an X-Y display, and using a phase-locked-loop circuit accurately determine the center frequency of a PSK signal. Should the operator wish to do so he may record certain signals on the instrumentation tape recorder for playback at a later time. This tape recorder can simultaneously record time (WWV)/microphone annotation,

demodulated audio, baseband spectrum information, and digital documentation.

Another important feature of the SSA is its self-testing capability. The Test Unit provides the capability to insert test signals at various points in the system with various modulation types, power levels, and data rates. Since the computer is controlling the operation of the system, many of the test procedures may be automated to the extent that the entire system may be exercised in a test mode with the push of a single button. Normally test functions are divided into separate areas so that individual components or component chains may be tested while the remainder of the system is in operation.

Accurate calibration routines are necessary if the system's use is to be optimized. Ideal filter characteristics are rarely realized and the errors must be considered. Computer algorithms have been developed so that system calibration may be automated. Calculating gain correction factors across the RF passband of a receiver is a common calibration procedure.

The SSA has a unique operator interface. The entire system operation has been placed on a series of menus which are displayed in a predetermined order to the operator. The operator is initially faced with a basic decision to make. He must decide which branch of the menu tree to travel. The operator indicates his choice by pressing the CRT where the appropriate response video "button" has been drawn. His response is detected by a touch panel which feeds the position of his finger to the computer which is then able to interpret his choice. The operator is then presented with another set of decisions to make. Menus will continue to be displayed until all of the necessary decisions have

been made such that analysis can begin. Only occasionally will the operator be required to enter information on the keyboard. The touch panel is designed to display the majority of the decisions required to run the system as well as detect the decision of the operator.

B. SCOPE OF THIS REPORT

This report documents the design, development, construction, and integration of two major modules and the software interface between the operator and the hardware of the SSA. The first of these two modules is the Signal Selector (SS). Its purpose is to allow any of the seven system receivers to independently select a signal source. The major components of the SS include power dividers and RF switches.

The second of the two modules is the Spectrum Receiver (SR). Four identical SRs are incorporated in the SSA.

The operator interface consists of a series of menus displayed on a video terminal. Each menu provides the operator with certain information about the system operation and requires that a decision be related to the computer which is controlling the operation. The computer stores certain information for the currently displayed menu so it can accurately interpret the input from the operator. This report examines the menu concept from source file to display on the operator's console and/or the CONRAC video monitor of the SSA.

II. SIGNAL SELECTOR

A. GENERAL

The Signal Selector SS is the major switching device in the SSA. All downconverted RF signals are fed to the SS for selected distribution to the four Spectrum Receivers, the two Frequency Receivers, the AN/WSC-3, and the Tektronix front panel spectrum analyzer via the Test Unit RF panel. Switching is controlled by the computer based on operator inputs. Initial design and construction efforts are documented in [1].

B. DESIGN CONSIDERATIONS

There are two major considerations in the design of the Signal Selector (SS). The first is its RF characteristics; the second is its physical size.

The SS was designed to allow any one of the seven system receivers to independently select one of seven input signals. The IF input signals are in three frequency ranges, i.e. three downlink signals 60 - 90 MHz, three uplink signals 110 - 140 MHz, and the tape playback 29.95 - 30.05 MHz. Components were selected to provide a flat response over all of the input frequencies with low loss.

Signal selection was to be under computer control; therefore, any switching device was to be TTL compatible in order to interface with the Control Bus Latch (CBL) boards which provide control information [2].

The SS panel is mounted on a swing gate on the back of a standard 19" equipment rack. Whereas a door will be placed on the back of the rack, it is desirable to mount all active components on the side of the panel mounted toward the inside of the equipment rack. A large volume of air will be forced through the middle of the rack so that the heat generated by the active components will be dissipated more readily. Passive components such as power dividers and adjustable attenuators may be mounted on the opposite side of the panel. Component size is restricted on the panel back side due to a two inch clearance between the panel and the rack door. Components mounted on the back side may not protrude more than the allotted two inches. In order for the swing gate to open completely, components mounted on the back side must be at least two inches away from the right hand edge. This constraint applies in general to all modules mounted on the swing gate.

C. OPERATION

Figure E.1 gives details on signal flow and path selection. Incoming IF signals are first divided into four or eight separate signals by a power divider. Table I lists all IF inputs and outputs. Unused power divider outputs are terminated with a 50 ohm load. All downlinks (RC1, RC2, and RC3), one uplink (XC3), and the tape playback signals are split into eight separate signals. Each of these signals feeds the appropriate input on the selector switch for the seven receivers. The eighth signal for the downlinks goes directly from the power divider to the Test Unit where upon selection it will be applied to the Tektronix spectrum analyzer input. The eighth signal for the uplink(XC3)/ tape playback is terminated in 50 ohms. Uplinks XC1 and XC2 are divided into

four separate signals which feed the appropriate inputs on all selector switches for SR1 to SR4.

An awkward arrangement exists between the tape playback and the uplink signal XC3. Signal XC3 was an added feature; therefore, its selection had to be accommodated by the SS. At the time the decision was made to include the new feature, there were only three downlink inputs, each being split eight ways, two uplink inputs, each being split four ways, and a tape playback input being split eight ways. Since XC3 was considered a bonus feature, its addition should cause minimum changes to the present design. It was decided that the tape input and the uplink XC3 input to the SS would share a common power divider and the appropriate signal would be selected by a SPDT RF switch one stage ahead of the power divider. The eight way power divider would allow the tape playback as well as uplink XC3 to be selected by any of the seven receivers. The consequence of this arrangement is clear; only XC3 or tape playback may be selected by any receiver at a time. Future changes and modifications should consider this awkward feature.

Selected distribution of the incoming IF signals is controlled by the computer in the normal operating environment. Control is exercised through two Control Bus Latch (CBL) boards. CBL9 controls signal selection for the Spectrum Receivers; whereas, CBL10 controls signal selection for the AN/WSC-3 (WP) and Frequency Receivers (FR). The bit mappings for CBL9 and CBL10 are listed in Table II. Appendix A contains an example of the software necessary to control the Signal Selector. CBL9 and CBL10 are connected to the SS via J19 and J20, respectively. The pinouts for these two jacks as well as the DC power connector are shown in Appendix B.

In order to select only one path through the RF switches the software must ensure that only one control bit is active (TTL low) for each switch at any time. Doing so is mandatory in order to prevent crosstalk and general signal degradation among the various paths.

D. TESTING

Testing of the Signal Selector, as well as most modules within the SSA, may be performed on one of three levels - laboratory, computer controlled (automated), or locally at the installation site. Laboratory testing may be as complicated and sophisticated as the available test equipment will allow. The Signal Selector may be exercised to its fullest with an RF signal generator, a device to monitor the output, and computer input or equivalent substitute to control the RF switches. There are no adjustments on the Signal Selector. This implies that once the characteristics have been observed and the results are not within specifications, parts will have to be replaced. Testing on any of the three levels should give the operator sufficient information to decide whether or not the module is operating properly.

1. Laboratory Testing

Initial SS testing was done with a HP8660C Synthesized Signal Generator providing the RF input, a HP8566A Spectrum Analyzer to monitor the output, and a "bit box" substituting for the computer control signal. Laboratory test procedures are detailed in Appendix F. The purpose of initial testing was to verify the operation of the RF switches. With the output monitoring device connected to a single SS output, the control information was changed so that each input was selected. The RF source was moved to the corresponding input. If the spectrum analyzer

indicated a sufficient output level, the signal path selected was determined as good. This procedure was repeated for each of the seven SS outputs.

SS test 2 determined the loss of each of the signal paths at the particular center frequency and the loss deviation over the frequency range of interest. A RF power meter was used to monitor the output. Input frequencies were swept according to the use of the selected input. Prior to making any measurements the RF signal generator output was measured by the RF power meter. Path loss is the difference between this power level and the SS output level. Path loss was determined over the range of interest and only the extreme deviations above and below the loss at center frequency were noted. The design loss for paths with eight way power dividers is 11 dB (9 dB theoretical + 1 dB for the power dividers + 1 dB for the RF switches). For paths containing a four way divider the loss was expected to be 3 dB less or 8 dB. In order to prevent contamination of the test results, all inputs and outputs which do not have an input signal or a measuring device, respectively, connected must have a 50 ohm termination.

2. Computer Controlled (Automated) Testing

When the module is actually installed in the SSA, its operation may be verified in a test environment (in addition to the normal operating condition) controlled by the PDP-11/34. The SSA has a built in receiver test signal generator which is also under computer control. Various power levels and modulation types may be defined for the test signal which then is inserted into one of the three antenna chains determined by the operator and controlled by the CPU. Unless input/output cables are physically swapped by the operator, the operator

must accept the receiver connected to the particular output as the monitoring device. In most cases this is sufficient to determine the go/no-go operation of the signal path selected.

Path loss measurements are not calculated directly in a separate test routine for the SS. Each receiver connected to a SS output has its own calibration routine which accounts for the SS path loss at different frequencies within the selected passband.

3. Local (On-site) Testing

If SS testing is required to be performed with the module removed from the SSA a test configuration similar to that for the laboratory is required. In this case test equipment may be limited. A RF signal generator with frequency range from 29 - 140 MHz and power level from -85 to 0dBm is sufficient for the input. Output monitoring devices may include RF power meters, spectrum analyzers, or RF voltmeters depending on the availability. Test procedures should resemble those described in the Laboratory Testing section.

4. Test Results

Test 1 was performed several times since faulty components were discovered during each test. Power dividers have been one hundred percent reliable in that no failures have been detected. The RF switches have had several different problems which should be noted for use in future testing. A common problem has been loss of control, i.e. switching the control bit high and low for a particular input causes no change in the path selection. Cases have been observed where the path could not be established and where the path could not be broken. Another problem noted was that the switch exhibited internal oscillations even without an input connected. (The input was a 50 ohm load.) At this writing all

possible paths are good and may be established or broken according to need and normal operation.

Once test 1 was satisfactorily completed for all paths, test 2 was conducted. The test produced the expected results. Table III is a tabulation of those results. It should be noted that this test essentially re-runs test 1. Depending on the purpose of the test, tests 1 and 2 may be run simultaneously.

In Table III the test results for a specific path are located at the intersection of the input column and the output row. The path loss at the center frequency is listed on the center line. Above this value is the greatest negative deviation, i.e. where less path loss was noted, from the center frequency path loss with the frequency where it occurred in parenthesis. The greatest positive deviation from center frequency path loss is listed with the frequency where it occurred on the third line.

Example: -.4(85.6)
 11.2
 +.1(70.0)

indicates a center frequency path loss of 11.2dB and the greatest negative deviation of .4 dB (i.e. loss = 10.8 dB) occurred at 85.6 MHz, and the greatest positive deviation of .1 dB (i.e. loss = 11.3 dB) occurred at 70.0 MHz. Input parameters for each type of input were:

<u>Input Type</u>	<u>Sweep Width</u>	<u>Center Frequency</u>
Downlink (RC1, RC2, RC3)	30 MHz	75 MHz
Uplink (XC1, XC2, XC3)	30 MHz	125 MHz
Tape playback (AS)	100 kHz	30 MHz

TABLE I
SIGNAL SELECTOR (SS) IF INPUTS AND OUTPUTS

INPUTS

J1	RC1, Antenna 1 downlink signal (RF1-J8)
J2	RC2, Antenna 2 downlink signal (RF2-J8)
J3	RC3, Antenna 3 downlink signal (RF3-J8)
J4	XC1, Antenna 1 uplink signal (RF1-J6)
J5	XC2, Antenna 2 uplink signal (RF3-J6)
J6	XC3, Antenna 3 uplink signal (RF3-J6)
J7	Audio Selector, tape playback (AS-J8)

OUTPUTS

J8	RC1 output to Test Unit RF panel (TR-J10)
J9	RC2 output to Test Unit RF panel (TR-J11)
J10	RC3 output to Test Unit RF panel (TR-J12)
J11	SR1 input (SR1-J1)
J12	SR2 input (SR2-J1)
J13	SR3 input (SR3-J1)
J14	SR4 input (SR4-J1)
J15	AN/WSC-3 input (WP-J6)
J16	FR1 input (FRA1-J1)
J17	FR2 input (FRA2-J1)

Note: Numbers in parentheses indicate module designation and jack number, i.e. AS-J8 indicates jack number 8 on the Audio Selector.

TABLE II
SIGNAL SELECTOR (SS) CONTROL BIT MAPPING

A. SS-J19 CBL9

Bit	Byte 0 (SR1)	Byte 1 (SR2)	Byte 2 (SR3)	Byte 3 (SR4)
D0	RC1	RC1	RC1	RC1
D1	RC2	RC2	RC2	RC2
D2	RC3	RC3	RC3	RC3
D3	XC1	XC1	XC1	XC1
D4	XC2	XC2	XC2	XC2
D5	XC3/AS	XC3/AS	XC3/AS	XC3/AS
D6	(NC)	(NC)	(NC)	(NC)
D7	(NC)	(NC)	(NC)	(NC)

B. SS-J20 CBL10

Bit	Byte 0 (XC3/AS)	Byte 1 (WP)	Byte 2 (FR1)	Byte 3 (FR2)
D0	XC3	XC3	XC3	XC3
D1	AS	AS	AS	AS
D2	(NC)	RC3	RC3	RC3
D3	(NC)	(NC)	(NC)	(NC)
D4	(NC)	(NC)	(NC)	(NC)
D5	(NC)	XC3/AS	XC3/AS	XC3/AS
D6	(NC)	(NC)	(NC)	(NC)
D7	(NC)	(NC)	(NC)	(NC)

- Notes: 1. All bits are active low.
2. NC = no connection

TABLE III
SIGNAL SELECTOR (SS) TEST RESULTS
DETAILED TEST 2

<u>OUTPUT</u>	(RC1) <u>J1</u>	INPUT (RC2) <u>J2</u>	(RC3) <u>J3</u>
J11 (SR1)	-.4(85.6) 11.1 +.1(70.0)	-.4(85.7) 11.2 +.1(71.3)	-.6(85.4) 11.2 +.15(71.4)
J12 (SR2)	-.3(86.8) 11.15 +.2(72)	-.35(85.9) 11.3 +.15(67.9)	-.6(85.4) 11.3 +.2(71.8)
J13 (SR3)	-.2(90) 11.2 +/- 0	-.3(87.2) 11.1 -.20(66.5)	-.55(86.9) 11.2 +.20(71.8)
J14 (SR4)	-.30(90.0) 11.1 +.10(70.8)	-.30(85.6) 11.05 +.20(69.0)	-.35(85.5) 11.1 +.15(69.0)
J15 (WP)	-.35(90.0) 11.1 +.10(71.0)	-.40(85.9) 11.05 +.10(68.0)	-.70(85.6) 11.05 +.15(70.9)
J16 (FR1)	-.35(85.4) 11.0 +.10(72.9)	-.35(86.3) 11.1 +.10(68.5)	-.60(86.6) 11.0 +.15(70.2)
J17 (FR2)	-.35(86.5) 11.1 +.10(69.0)	-.35(86.5) 11.0 +.20(68.7)	-.60(88.0) 10.9 +.25(69.2)
J8 (TR)	-.60(86.7) 10.3 +.25(68.0)	(NC)	(NC)
J9 (TR)	(NC)	-.60(86.9) 10.4 +.25(65.4)	(NC)
J10 (TR)	(NC)	(NC)	-1.0(88.0) 10.4 +.30(69.0)

TABLE III (continued)
SIGNAL SELECTOR (SS) TEST RESULTS
DETAILED TEST 2

OUTPUT	INPUT			
	(XC1) J4	(XC2) J5	(XC3) J6	(AS) J7
J11	-.20(130.8) 7.7	-.10(134.4) 7.9	-.60(110.2) 12.1	+/- 0 11.3
(SR1)	+.2(113.3)	+/-0	+.10(130.0)	+/- 0
J12	-.15(130.0) 7.65	-.10(132.5) 7.9	-.6-(111.0) 12.1	+/- 0 11.3
(SR2)	+.20(114.0)	+.10(113.0)	+.1-(132.0)	+/- 0
J13	-.20(130.9) 7.8	+/- 0 7.6	-.60(111.3) 12.1	+/- 0 11.3
(SR3)	+.20(112.8)	+.20(140.0)	+.10(132.2)	+/- 0
J14	-.20(131.0) 7.5	+/- 0 7.6	-.70(110.0) 12.1	+/- 0 11.2
(SR4)	+.20(116.2)	+.10(140)	+/- 0	+/- 0
J15 (WP)	(NC)	(NC)	-.70(110) 11.9	+/- 0 11.1
			+.10(132.0)	+/- 0
J16	(NC)	(NC)	-.70(110.0) 12.0	+/- 0 11.2
(FR1)			+.10(137.4)	+/- 0
J17	(NC)	(NC)	-.60(110.0) 12.0	+/- 0 11.2
(FR2)			+.10(127.8)	+/- 0

Example: -.4(85.6)
 11.2
 +.1(70.0)

This indicates a center frequency path loss of 11.2dB and the greatest negative deviation of .4 dB (i.e. loss = 10.8 dB) occurred at 85.6 MHz, and the greatest positive deviation of .1 dB (i.e. loss = 11.3 dB) occurred at 70.0 MHz. Rows correspond to outputs; columns correspond to inputs.

III. SPECTRUM RECEIVERS (SR)

A. GENERAL

The purpose of the Spectrum Receivers is to downconvert the input IF to one of four baseband center frequencies which is then converted to a digital signal for processing by an Analogic AP-400 Array Processor. The spectrum produced by the array processor is displayed on a 19" CON-RAC video monitor. The Spectrum Receiver also provides its baseband output to an audio selector where either of the two lowest bandwidth signals may be input to an audio instrumentation recorder. The Spectrum Receiver baseband signal is routed via the audio selector to the oscilloscope in the test unit where the time domain output may be observed. Normal SSA operations call for a total of four Spectrum Receiver chains. Each Spectrum Receiver chain includes the Spectrum Receiver as well as the analog-to-digital converter (AD) and the array processor (AP) which follow it. Initial design considerations and construction accomplished prior to this report are documented in [1].

B. DESIGN CONSIDERATIONS

1. Input/output Specifications

The signal flow from the antenna to the spectrum displays is shown in Figure 3.1. Received power levels of normal SATCOM signals are not expected to exceed -85 dBm, the maximum for SATCOM signals. This level in the antenna will produce a signal of -47 dBm at the Signal Selector input. The amplified signal will be 180 MHz below the received frequency since the RF unit mixes all inputs with a 180 MHz local

oscillator. A low-side mix is performed which maintains the order of the received spectrum.

Signals at the input to the Signal Selector may be channeled to one of seven receivers: four Spectrum Receivers, an AN/WSC-3 and two Frequency Receivers. Maximum power SATCOM signals provided to any of the Spectrum Receiver chains must be downconverted to baseband (below 2 MHz) with a maximum 50 ohm output of 7.5 volts peak. The A/D converter which follows the Spectrum Receiver samples the baseband at a rate which corresponds to one of four processing bandwidths in the Spectrum Receivers. The Analogic AP-400 Array Processor output is a FFT of its input samples. The entire receiver chain must operate linearly when receiving the maximum SATCOM signal.

In addition to the maximum SATCOM signal level of -85 dBm, anticipated RFI signals may reach -25 dBm in power. Capability to handle signals in this range must be incorporated into the Spectrum Receiver design.

Any control signals required to operate the Spectrum Receiver will be provided by a CBL board [2]. Each CBL may provide up to 32 bits of control information at TTL levels; therefore, control circuits within the receiver must conform to normal TTL specifications.

2. Filtering

The receiver must be able to process signals in one of four specified bandwidths - 3 kHz, 30 kHz, 80 kHz, and 600 kHz. The primary signals of interest on FLTSATCOM and GAPFILLER satellites have a bandwidth of 25 kHz. In addition to the 25 kHz Navy channels in FLTSATCOM the Air Force has twelve 5 kHz signals of low interest to the Navy. FLTSATCOM also supports a 500 kHz DOD wideband channel. It is

also of secondary interest. GAPFILLER has a single 500 kHz transponder which contains twenty 25 kHz channels. The SSA must have the capability to observe the entire 500 kHz transponders and provide a fine grain analysis of interfering signals. Filtering to accomplish this is performed at two major levels in the receiver.

a. Bandpass

The first set of bandpass filters is located in the IF. These filters are used to pass the signal of interest and reject all unwanted signals, including strong RFI, outside the passband. To provide adequate attenuation of RFI signals and reduce the effects of aliasing and foldover in the digital processing later, high Q filters were specified. The passband must be flat within 0.5 dB to accurately reproduce the satellite signals. An additional parameter, the center frequency, is needed to completely specify the bandpass characteristics of each filter. The difference between the bandpass center frequency and 30 MHz will determine the center frequency of the baseband spectrum. (30 MHz is a constant frequency local oscillator signal which provides the final translation of the IF to baseband.)

It is at baseband where the digital processing is done to produce the spectrum display. The sampling rate of the analog-to-digital converter is determined by the frequency range of the baseband spectrum. By the sampling theorem the sampling rate must be at least twice the highest frequency to be analyzed. Given this relationship a trade off must be made between the position of the baseband spectrum and the sampling rate. The position must be high enough so that spectral components which pass through the 0 Hz frequency line are folded-over at a minimum level and it must be low enough so that the sampling frequency

is in the range of the A/D converters. For the four bandwidths the following IF parameters were chosen:

Display BW (kHz)	IF f(l) (MHz)	IF f(c) (MHz)	IF f(u) (MHz)
3	29.9935	29.9955	29.9975
30	29.950	29.966	29.982
80	29,840	29.895	29.950
600	29.2	29.5	29.8

where: f(l) = lower .5 dB cutoff frequency
 f(c) = center frequency
 f(u) = upper .5 dB cutoff frequency

Actual bandwidths are larger than the display bandwidths to ensure a maximally flat passband. When mixed with the 30 MHz local oscillator the corresponding baseband parameters are:

Display BW (kHz)	BB f(l) (kHz)	BB f(c) (kHz)	BB f(u) (kHz)
3	2.5	4.5	6.5
30	17.0	34.0	51.0
80	50.0	105.0	160.0
600	200.0	500.0	800.0

Using the 600 kHz display bandwidth as an example the fold-over level in the passband may be calculated. Since the upper 35 dB down point of the filter was specified as 30.2 MHz, frequency components will be at least 35 dB less at the lower edge of the baseband range of interest, e.g. when the 30.2 MHz IF point is mixed with the 30 MHz local oscillator it translates to -200 kHz which folds over to +200 kHz, 35 dB down, but adding to the frequency component translated to that point already from 28.8 MHz in the IF passband. Consider a hypothetical test signal with a uniform frequency distribution from 28.5 to 30.5 MHz. If this signal were passed through the 600 kHz bandpass filter and then mixed with a 30 MHz local oscillator, the spectral component observed on

a spectrum analyzer at 200 kHz would be the sum of the unattenuated (not considering filter insertion loss) signal at +200 kHz and the folded-over signal 35 dB down at -200 kHz.

b. Lowpass

The second major filtering operation is performed after the IF has been converted to baseband. Lowpass filtering the baseband using a sufficiently high cutoff frequency allows the frequency range of interest to be passed with minimum attenuation and distortion of the signal characteristics. Out-of-band components will be significantly reduced. It is necessary to reduce the aliasing effects caused by digital processing which follows.

Desirable lowpass filter characteristics were considered to be a flat passband and a monotonically decreasing skirt. Using this criterion a third order Butterworth filter was specified. A third order Butterworth filter will provide at least 10 dB of attenuation at frequencies 1.5 times the 3 dB cutoff frequency (or, equivalently, 2.5 times the 0.2 dB cutoff frequency.)

Specifications for the lowpass filters are:

Specification	BW1	BW2	BW3	BW4
Passband ripple (max)	+/-0.2 dB	+/-0.2 dB	+/-0.2 dB	+/-0.2 dB
3.0dB cutoff frequency	12 kHz	97 kHz	310 kHz	1.5 MHz
10dB cutoff frequency	18 kHz	146 kHz	465 kHz	2.2 MHz

The DATEL FLT-U2 Universal Hybrid Active Filter was selected as the active filter for the two lowest bandwidths. The FLT-U2 uses a state variable implementation of the lowpass filter characteristics. With one chip a three pole Butterworth filter was constructed. Use of these chips to implement the filter is contained in Appendix K.

FLT-U2s could not be used for the 80 kHz and 600 kHz bandwidths because of its upper frequency limitation. Passive filters with the same basic specifications were used instead. Bandwidth three uses a filter with approximately 0.2 dB insertion loss. Bandwidth 4 requires no additional selectable filter as it is the largest bandwidth. Each of the four bandwidths benefits from a lowpass filter at the input to the lowpass filter assembly, A1. This lowpass filter has a 3 dB cutoff frequency of 1.5 MHz. This filter essentially constitutes the bandwidth 4 filter. When bandwidth 4 is selected this filter is the only lowpass filter in the circuit.

It is obvious that when the IF bandpass filter for 30 kHz bandwidth is selected the corresponding baseband lowpass filter must also be selected. The bandpass filters are switched with a SP4T RF switch whose four control inputs are bit simple, active low; whereas, the 4-to-1 analog switch used to select the baseband signals uses a two bit binary, active high logic. A decoding circuit built around U1 (7400) was included on the printed circuit board containing the lowpass filters so that the two filter banks could be switched simultaneously with the same computer control signal.

3. Mixing

a. Local Oscillator Frequency

IF input frequencies may be in one of three ranges: 60 to 90 MHz for downlink signals; 110 to 140 MHz for uplink signals; and 30 MHz +/- 50 kHz for tape playback signals. The local oscillator frequency range capability is 0.1 to 160 MHz in steps of 10 Hz. When the operator chooses the receiver bandwidth and uplink or downlink, he automatically

specifies the local oscillator frequency according to the following formula:

$$f(lo) = f(i) + f(rf) - 180 \text{ MHz}$$

where $f(lo)$ = local oscillator frequency
 $f(rf)$ = RF input frequency
 $f(i) = f(1) = 29.9955 \text{ MHz}$ for BW1
 $f(2) = 29.966 \text{ MHz}$ for BW2
 $f(3) = 29.895 \text{ MHz}$ for BW3
 $f(4) = 29.5 \text{ MHz}$ for BW4

It is significant to note that this formula applies only to downlink signals. Since the incoming downlink IF ranges from 60 to 90 MHz the Rockland frequency synthesizer is capable of producing frequencies above the incoming signals. Downlink local oscillator frequencies range from 89.5 MHz ($29.5 + 60$) to 119.9955 MHz ($29.9955 + 90$).

Uplink RF frequencies range from 290 to 320 MHz which means that downconverted IF signals at the input to the Spectrum Receivers will be in the range from 110 to 140 MHz. To have the local oscillator frequency above the incoming IF would require a frequency synthesizer range of 139.5 MHz ($29.5 + 110$) to 169.9955 MHz ($29.9955 + 140$). This is not possible with the currently installed local oscillators. Therefore, the local oscillator frequency will have to be below the incoming IF and subsequently will not provide a necessary spectrum inversion. For proper spectrum display an even number of spectrum inversions is necessary. The spectrum for uplink signals will be displayed in reverse order. Local oscillator frequencies for observing uplink signals are calculated according to the following formula:

$$f(lo) = f(rf) - 180 - f(i) \text{ MHz}$$

where $f(lo)$, $f(rf)$, and $f(i)$ = those used for the downlink calculation.

b. Local Oscillator Level

The mixers selected for this design were the Merrimac DMM-4-250 double balanced mixer. Useful local oscillator drive level ranges between +10 and +20 dBm which corresponds to the output available from the Rockland 5610 synthesizer to be used as the local oscillator. Nominal drive power is +17 dBm. Within the useful range, the mixer exhibits an 8 dB maximum conversion loss.

4. Amplification and Attenuation

Input power levels for normal SATCOM signals will range between -135 and -85 dBm; however, provisions have been made to accept input RFI (Radio Frequency Interference) inputs up to -25 dBm at the expense of degrading the noise figure of the receiver. Three receive modes were defined to allow signal reception in one of three ranges according to signal strength. The NORMAL SATCOM mode will allow observation of signals up to -85 dBm; RFI LOW mode, signals up to -55 dBm; and RFI HIGH mode, signals up to -25 dBm. To allow for a large dynamic range a step attenuator was selected. It will be computer controlled and provide programmable attenuation from 0 to 88 dB in 8 dB steps. For reception of SATCOM signals the attenuation will nominally be set for 16 dB.

To look at signals in the next range, maximum of -55 dBm, an additional 32 dB attenuation would be enabled. Maximum signal strength observable without saturation is -25 dBm. An additional 64 dB attenuation is required to change modes from the SATCOM mode to a mode where a -25 dBm signal may be processed without going into nonlinear operation. These two modes which use extra attenuation should only be used to look at strong RFI signals. When extra attenuation is enabled the noise temperature increases and slightly reduces the signal-to-noise ratio. In

the RFI modes the signal to noise ratio is reduced but is of little concern because the signal of interest, the RFI in most cases, has a high signal level.

5. LPF Output

With -85 dBm being the maximum power level for a normal SATCOM signal, the receiver must produce its maximum baseband voltage output of 7.5 volts peak with a received signal at the maximum level. The output of the LPF assembly is provided to the analog-to-digital converter board and to the audio selector via RG-223 coaxial cable. The characteristic impedance of RG-223 is 50 ohms which implies it must have a 50 ohm load to prevent reflections. The driving amplifier must have a high drive capability and a large unity gain-bandwidth product. The solution to the drive and bandwidth problems was the Burr-Brown 3553 "Wide Band Fast Slewing Buffer Amp". It provides 200 ma of drive current over a +/- 10 volt range. Unity gain-bandwidth is 32 MHz. At the A/D input the signal goes through a two-thirds voltage divider which reduces the 7.5 volts signal to the maximum input of 5 volts required for full scale A/D operation.

6. Computer Control

For the receiver operation to be completely automated an interface with the computer was provided. Control Bus Latch (CBL) board 14 was assigned to the group of four Spectrum Receivers. CBL14 distributes its 32 bit output to each SR via the Receiver Interface (RI) which also contains control distribution for the Frequency Receivers (FR). See Figure J.1 for details of the Spectrum Receiver control distribution.

7. Noise Temperature Calculations

Noise power level was a major consideration in the design. Amplifiers with low noise figures were used in the receiver front end to keep noise temperature contributions low from the early stages. Minimum insertion loss was specified for passive components in order to reduce their noise temperature contribution due to the extra attenuation in the signal path.

Figure 3.2 gives a summary of the noise temperature calculations and shows where the contributions occur. The noise temperatures listed are the contributions of each component (or group of components) referenced to the system antenna inputs. Noise temperature calculations are based on the formula

$$T = [290(F-1)/G] \text{ Kelvins}$$

where: T = Noise temperature
F = noise figure of component
G = system gain to the input of the component
being considered.

A system gain of +38 dB was assumed prior to the input to the signal selector (SS). Noise temperature to the input of the SS was assumed to be 550 K. Consecutive passive components were lumped together as one passive element with the total attenuation approximating the noise figure. This value of attenuation is used as F in the formula when it is converted to its linear equivalent.

C. OPERATION

The entire SSA will be controlled from the operator's console using the menu concept of operation to be explained in Chapter 4. The operator normally will not explicitly specify the operating parameters of the Spectrum Receivers. Parameters are implicit in selections made on the menus regarding spectrum display on the left or right screen. Suppose the operator has made a selection which allows him to view the spectrum of a CW test signal at 255 MHz with a power level equivalent to a received signal at the antenna of -93 dBm. Display bandwidth is 30 kHz. Figures J.2 and 3.3 show signal flow through the Spectrum Receiver.

In the RF stages the signal is amplified by 38 dB and downconverted by 180 MHz. Thus the signal at the Signal Selector input is 75 MHz, at -55 dBm. Passing through the Signal Selector the signal is attenuated by approximately 11.5 dB. This value varies slightly depending upon the components in the selected path. This signal is provided to the Spectrum Receiver input. MX1 mixes the incoming signal with a +13 dBm local oscillator signal at 104.896 MHz. Signal level is now approximately -74.5 dBm at 29.896 MHz, the center frequency of FL3. AMPL1 provides +22 dB gain prior to signal filtering by FL1. FL1 passes the difference frequency generated by MX1 and eliminates the sum frequency. In addition to reducing the effects of out-of-band signals and RFI, it cuts down the amount of noise power allowed to enter the receiver. With the +22 dB gain of AMPL1 and the 3.5 dB insertion loss of FL1 the signal level has reached -56.0 dBm. A splitting operation is performed at this stage to provide four possible choices of bandwidth. The -56.0 dBm signal is evenly divided into four signals each down by the 6 dB theoretical loss plus 1 dB insertion loss. Each of the four paths has a

bandpass filter to be selected according to the spectrum display bandwidth desired. Bandpass filter FL5 (BW = 600 kHz) has a design insertion loss of 12 dB, the largest among FL2, FL3, FL4, and FL5. Attenuators AT1, AT2, and AT3 were necessary to equalize the loss among the four signal paths. From the output of the power divider, PD1, to the input of S1 the signal undergoes a selected filtering operation and is attenuated by 12 dB. Signal level at the switch input is -75.0 dBm. S1, under computer control, selects one of the four bandwidths. For a 30 kHz display bandwidth bit 5 in the appropriate byte of CBL14 is active. (See Table IV for control bit mapping.) Considering the switch has a maximum insertion loss of 1 dB the signal level is now -76.0 dBm. AMPL2 is identical to AMPL1 and provides +22 dB gain before the signal passes through the step attenuator. When observing normal SATCOM signals this attenuator is set to 16 dB by asserting bit one in the appropriate byte of CBL14. In addition to the 16 dB programmed, the step attenuator has an insertion loss of .4 dB per step. The output of the step attenuator is again passed through a bandpass filter to reduce out-of-band noise contributions in anticipation of a large amount of amplification ahead. Trimmer AT5 allows accurate calibration in accordance with the input/output specifications. Accounting for the 16.4 dB step attenuator loss and the 0.7 dB FL6 insertion loss, signal level is -71.1 dBm. In order to determine the theoretical setting for AT5, the gain from AT5 to the receiver output must be known. For maximum receiver output of 7.5 volts peak (or 19.5 dBm into a 50 ohm load), the input voltage to A1 must be .173 vrms; therefore, the gain is 29.7 dB. Considering the 80 dB gain of AMPL3, the 6 dB loss of AT6, the 8 dB loss

of MX2, and the 29.7 dB gain of A1, the input level to A1 can be expressed as:

$$\begin{aligned} & \text{FL6 output level} - \text{AT5 attenuation} + \\ & \text{AMPL3 gain} - \text{AT6 attenuation} - \\ & \text{MX2 conversion loss} + \text{A1 gain} = 19.5 \text{ dBm} \end{aligned}$$

or:

$$-71.1 - X + 80 - 6 - 8 + 29.7 = 19.6 \text{ dBm}$$

Solving for X, the total theoretical loss (including its own insertion loss) to be set for AT5 is 5.1 dB attenuation. The nominal setting for AT5 is well within the 0 - 20 dB range. This value is expected to vary under normal operating conditions due to the accumulated deviation of the actual values of gains and losses from specifications. MX2 performs the same function as MX1 except that the local oscillator is a constant 30 MHz at +13 dBm. At the output of MX2 the original signal has been downconverted to baseband. Signal frequency is $30 \text{ MHz} - 29.896 \text{ MHz} = 34 \text{ kHz}$.

Assembly A1 performs two important functions. It amplifies the signal to an appropriate level for the A/D input and filters out high frequency components according to the display bandwidth selected. Figure J.12 shows signal flow through A1; Figure J.13 is the schematic for A1. In order to reduce unwanted signals which may have been introduced in the RG-223 coaxial cable, A1 has a differential input which feeds FL7. FL7 is a lowpass filter with a 3 dB cutoff frequency of 1.5 MHz allowing a flat response within 0.2 dB for signals of interest and greatly reduces unwanted signals such as the sum frequency produced by MX2. The amplifier circuit around U1 has a differential input and provides a voltage gain of 5. (Gain = $(R4/R2) = 10K/2K = 5$.) The output DC offset for bandwidth 3 and 4 (80 kHz and 600 kHz, respectively) may be adjusted

with R7. U1 simultaneously feeds four paths, one of which will be selected. The lowpass filter U2 has a 3 dB cutoff frequency of 12 kHz. Since it is an active filter a gain of 1 is specified. Lowpass filter U3 has a 3 dB cutoff frequency of 97 kHz. It is also implemented with a DATEL FLT-U2 and has a gain of 1. The third path, for BW3, contains a passive filter FL8 whose input and output impedances are 3K ohms. R33 is a terminating resistor for FL10 when this path is selected. Resistor-capacitor network R35-R36-R37-R38- C6-C7 forms a compensating network to reduce the variations in frequency response of the circuit observed without the compensating network. The values of the compensating network were determined empirically.

All four signal paths described above feed a CD4052BE, 4-to-1 differential input analog switch. One of these paths is selected according to the display bandwidth selected. When bandwidth 1, 2, or 4 is selected the voltage gain of U6 is 5/3.02.

$$\text{Gain1} = (R40/R17) = 10K/6.04K = 5/3.02$$

$$\text{Gain2} = (R40/R28) = 10K/6.04K = 5/3.02$$

$$\text{DC Gain4} = [R40/(R35 + R36)] = 10K/6.02K = 5/3.01$$

The voltage in path 3 was reduced by a factor of .5 at the output of FL8; therefore, when bandwidth 3 is selected U6 has a gain of 10/3.01. [Gain3 = (R40/R33) = 10K/3.01K = 10/3.01] By using this technique of providing separate input resistors for U6 on the input side of U4 the gain of U6 was selectable according to the bandwidth. Thus at the output of U6 each bandwidth has the same effective gain. Amplifier U7 increases the signal level [Gain = (R44/R42) = 8.06K/2K = 4.03] and feeds the two wideband buffer amplifiers, U8 and U9. The Burr-Brown 3553AM was selected because of its drive capability and frequency response. With a 50 ohm load its gain is specified as 0.92. The LPF assembly has

two outputs, J4 for the A/D output and J5 for the Audio Selector/Test Unit output. The overall gain of the LPF is stated as:

$$\text{Gain(U1)} \times \text{Gain(U6)} \times \text{Gain(U7)} \times \text{Gain(U8)} = \text{LPF Gain}$$

For the given individual gains of the LPF component amplifiers, the overall gain of assembly A1 is 30.666 or 29.7 dB.

D. TESTING

As was mentioned in Chapter 1 for the Signal Selector, testing may be performed on one of three levels - laboratory, computer controlled (automated), or locally at the installation site. In the laboratory sophisticated test equipment is available and testing occurs in a very controlled environment. The Spectrum Receivers required a series of laboratory tests to verify the designed operation. Various tests ranging from a simple verification of signal level within the receiver to plotting frequency response curves for each of four bandwidths was performed. With these tests the receiver was accurately calibrated and the design parameters were verified.

Once the receiver was adjusted to specifications it was placed in position in the SSA equipment rack where under computer control each of the four Spectrum Receivers in the SSA may be calibrated further using a built-in test signal generator and the array processors, also under computer control. Computer algorithms can be developed to compensate for small values of ripple in each of the passbands; correction values will be stored in memory and will be applied in real-time operation by the computer.

1. Laboratory Testing

The completed Spectrum Receiver was submitted to a rigorous series of tests for calibration as well as for verification of the designed operating parameters. Laboratory testing allowed accurate alignment of each Spectrum Receiver constructed. Appendix L contains the detailed instructions for each test or alignment procedure required. Basically tests were divided into three parts: (1) testing the LPF, (2) aligning the SR, and (3) testing the SR as a complete module.

The proper alignment of the lowpass filter assembly A1 was critical to the operation of the receiver and was to be completed before the LPF was installed. The LPF has three adjustments for DC offset and two adjustments for locating the cutoff frequency of the two adjustable lowpass filters. With the DC offset for bandwidths 3 and 4 adjusted, alignment of bandwidths 1 and 2 can proceed.

Each of the active filters had to be adjusted to give the proper frequency response when selected. Adjustment of the DC offset level for the active filters interacted with the frequency response adjustment of its respective filter. This interaction was dealt with by separately adjusting each parameter initially then alternately adjusting DC offset and frequency response. The circuit configuration for bandwidths 1 and 2 produced reliable frequency response characteristics with minimum DC offset.

Frequency response curves were plotted for each of the four bandwidths by using a sweep frequency generator, a true RMS voltmeter, and a X-Y plotter. The plots were done at baseband for the LPF assembly and were later run for the entire SR using RF input frequencies and

plotting the response of the baseband output. After the complete alignment of the LPF unit, it was installed in the SR.

To properly test the Spectrum Receiver, local oscillators of the proper frequency range and output had to be connected. By knowing the input and output power specifications, the overall gain was adjusted with bandwidth 4 selected. Bandwidths 1, 2, and 3 were then selected and the gain for each was adjusted so that the receiver gain was constant regardless of which bandwidth was selected. During this alignment procedure the input frequency remained constant, but the local oscillator frequency changed with the selection of each bandwidth. Alignment of each bandwidth must be accomplished using an IF frequency corresponding to the center frequency of the selected bandpass filter. The calibration and alignment at this frequency will be used as a reference in other test procedures such as the frequency response.

With the alignment of each of the bandwidths complete the receiver was ready for design verification testing. It had essentially passed the first test in that the Master Gain Control (AT5) was able to adjust the output to provide the specified gain in bandwidth 4. Attenuators AT1, AT2, and AT3 matched the gains for bandwidths 1, 2, and 3, respectively, to that of bandwidth 4. After showing that these attenuators could be used to set up the receiver to its designed center frequency gain specification, each attenuator was individually varied from its position of minimum attenuation to its position of maximum attenuation to obtain its operating range.

Since the noise temperature affects the minimum discernible signal, its value was experimentally measured. This measurement was performed so that the amount of noise power at the output would be known.

Receiver operation must be linear for received signals to be accurately downconverted, processed, and displayed. To determine the linear region of operation the input vs. output curve was plotted for each receiver. On each curve the point where the actual output deviates from the linearly predicted output by 1 dB, the 1 dB compression point, has been noted. Receiver operation for input powers greater than that determined at the 1 dB compression point will be in the nonlinear region of its characteristic curve.

Accurate representation of satellite signals over the display bandwidth is dependent upon the bandpass characteristics of the receiver. Each receiver will have slightly different characteristics since the actual parts used are different. Without major modifications the bandpass characteristics may not be changed, only observed and noted. Large deviations from the designed performance will be cause for redesign. Bandpass characteristics are best displayed with the use of a sweep signal generator and an X-Y plotter. The test procedures in Appendix L describe two methods for plotting the frequency response characteristics. Instead of using an X-Y plotter the same results may be obtained by tabulating a set of observation points and plotting them by hand. The former method is preferable.

2. Computer Controlled (Automated) Testing

Although each receiver evolved from a common design, the operating characteristics vary from receiver to receiver. Once the receiver has been aligned and placed under computer control of the SSA then an automated procedure can rapidly run calibration tests for each bandwidth of that receiver and store a look up table of correction factors to be applied to the output of the array processor. Hence the characteristics of the Spectrum Receiver chain may be made quite flat and even approach the ideal case.

Under normal conditions the SSA operator will periodically subject the receivers to a series of automated tests to ensure their proper operation. The SSA has the capability to inject its own test signal and monitor the output of each receiver. Also the SSA may selectively inject the test signal into one of three antenna paths allowing the test signal to be moved from point to point to locate failures by the process of elimination. The computer algorithms are limited in their trouble diagnosis in that the source of a problem may be localized only to a receiver chain which includes the Spectrum Receivers, the analog-to-digital converter boards, and the array processors. The receiver chains are continuous from the input of the SR to the output of the array processor. When the source of trouble has been reduced to a receiver chain the operator or technician must aid in determining the exact cause by systematically swapping cables and, in some cases, monitoring outputs with external devices.

3. Local (On-site) Testing

It is not anticipated that any detailed trouble shooting will have to be done at the installation site. Most problems located in the Spectrum Receivers will be remedied by simply replacing the defective receiver with a complete spare. Each installation site is expected to have on hand an extra receiver solely for this purpose. Should on-site testing be required defective components may be located by injecting a signal in the input jack (J2) and following it through each component with an output monitoring device such as an RF voltmeter or a spectrum analyzer. An alternative to this method would be to isolate each component for individual analysis. Unless signal generators are available for use as local oscillators, MX1 and the components from MX2 (inclusive) to the receiver output will not be subjected to the test. If tested individually the LPF input would have to be a signal generator whose output frequency range covered DC to 2 MHz.

4. Test Results

Each of the tests listed in Appendix L (with the exception of the second method of obtaining frequency response) was performed on each of the six receivers built. All six units met specifications with the exception of several of the bandpass characteristics. Problems noted were slight deviations from the specified bandpass response. Either the cutoff frequencies or the passband ripple were out of specifications. These deviations will be corrected when the receivers are placed in normal operation and the computer does a calibration sweep for each bandwidth.

The results of measuring the signal levels within the receiver for each bandwidth are tabulated in Table V. Lowpass filter characteristics observed are Figures 3.4 to 3.7. A typical noise temperature calculation is shown in Figure 3.8. Power in vs. power out curves are Figures 3.9 to 3.12. Figures 3.13 to 3.16 illustrate the frequency response of each of the four bandwidths. Receiver specifications are listed in Table VI. These specifications have been verified experimentally.

TABLE IV

RECEIVER INTERFACE (RI) - CBL14 BIT MAPPING

RI-J9

<u>Bit</u>	Byte 0 (SR1)	Byte 1 (SR2)	Byte 2 (SR3)	Byte 3 (SR4)
D0	8 dB	8 dB	8 dB	8 dB
D1	16 dB	16 dB	16 dB	16 dB
D2	32 dB	32 dB	32 dB	32 dB
D3	32 dB	32 dB	32 dB	32 dB
D4	BW1	BW1	BW1	BW1
D5	BW2	BW2	BW2	BW2
D6	BW3	BW3	BW3	BW3
D7	BW4	BW4	BW4	BW4

TABLE V

MEASURED SIGNAL LEVELS WITHIN THE SPECTRUM RECEIVER

<u>Junction</u>	<u>Expected</u>	POWER LEVELS (dBm)			
		measured			
		<u>BW1</u>	<u>BW2</u>	<u>BW3</u>	<u>BW4</u>
Input to SS-J1	-55.0	-55.0	-55.0	-55.0	-55.0
Output SS-J11	-66.5	-66.0	-66.0	-66.0	-66.0
AMPL1 - FL1	-52.5	-49.0	-49.0	-49.0	-49.0
FL1 - PD1	-56.0	-52.0	-52.0	-51.0	-51.0
S1 - AMPL2	-76.0	-69.0	-69.0	-68.5	-69.0
AMPL2 - AT4	-54.0	-45.0	-45.0	-44.0	-44.0
FL6 - AT5	-71.1	-63.0	-62.5	-62.5	-62.0
AT5 - AMPL3	-76.2	-79.5	-79.5	-79.0	-79.0
AT6 - MX2	- 2.2	- 5.5	- 5.0	- 4.5	- 4.5
MX2 - A1	.069*	.069*	.069*	.072*	.072*
SR output J4	2.11*	2.11*	2.11*	2.11*	2.11*

* denotes voltage readings (volts rms).

TABLE VI
SPECTRUM RECEIVER (SR) SPECIFICATIONS

Input Frequency Range:

Downlink	60 - 90 MHz
Uplink	110 - 140 MHz
Tape play	30 MHz +/- 50 kHz

Local Oscillator Frequency

Downlink	90 - 120 MHz
Uplink	80 - 110 MHz
Tape play	60 MHz

IF Bandwidths

BW1 (30 kHz)	4 kHz
BW2 (30 kHz)	32 kHz
BW3 (80 kHz)	110 kHz
BW4 (600 kHz)	600 kHz

Input to Signal Selector vs Output of Spectrum Receiver

-70 dBm	--->	.375 vrms
-60 dBm	--->	1.187 vrms
-55 dBm	--->	2.11 vrms
-47 dBm	--->	5.3 vrms (Maximum SATCOM signal)

System Gain

SS-input-to-SR-output gain (downlink)	74.5 dB
SR-input-to-SR-output gain (typical)	85.5 dB

Noise Temperature Contribution

55 K (typical)

1 db Compression Point

-45 dBm input power (input to SS)

DC Voltage Requirements

+ 5 v	200 ma
- 5 v	-200 ma
+15 v	750 ma
-15 v	185 ma

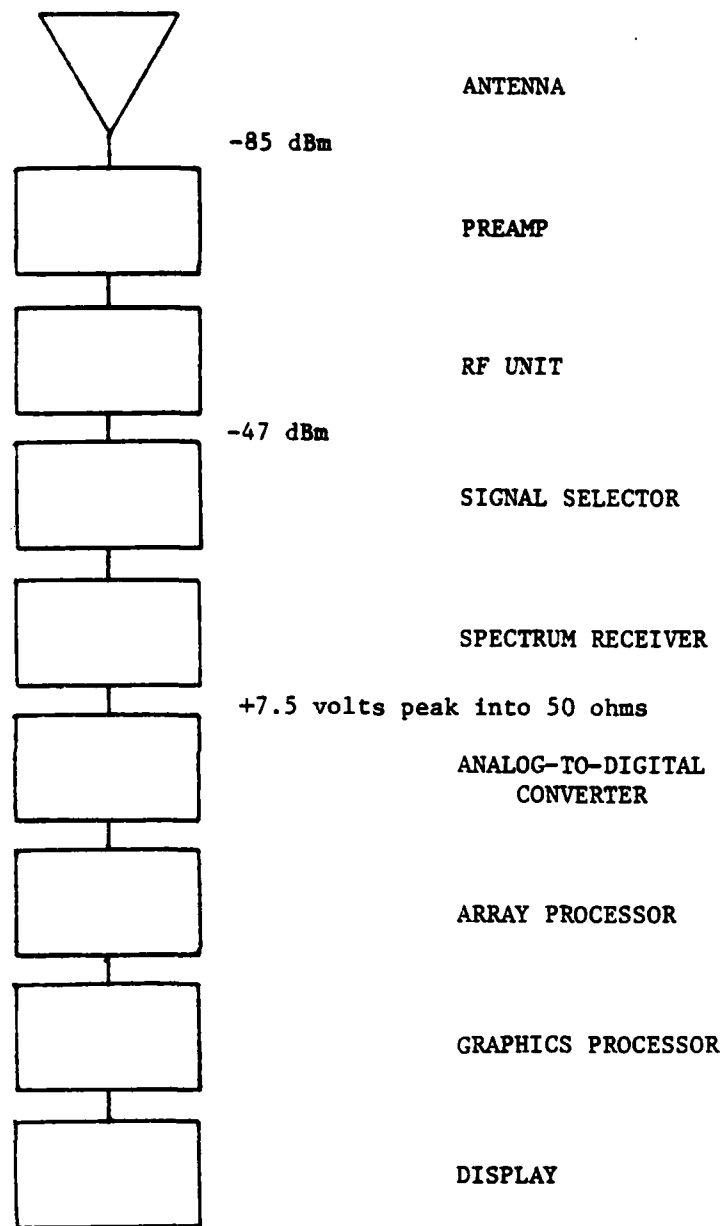


Figure 3.1
Signal Flow From Antenna To Display

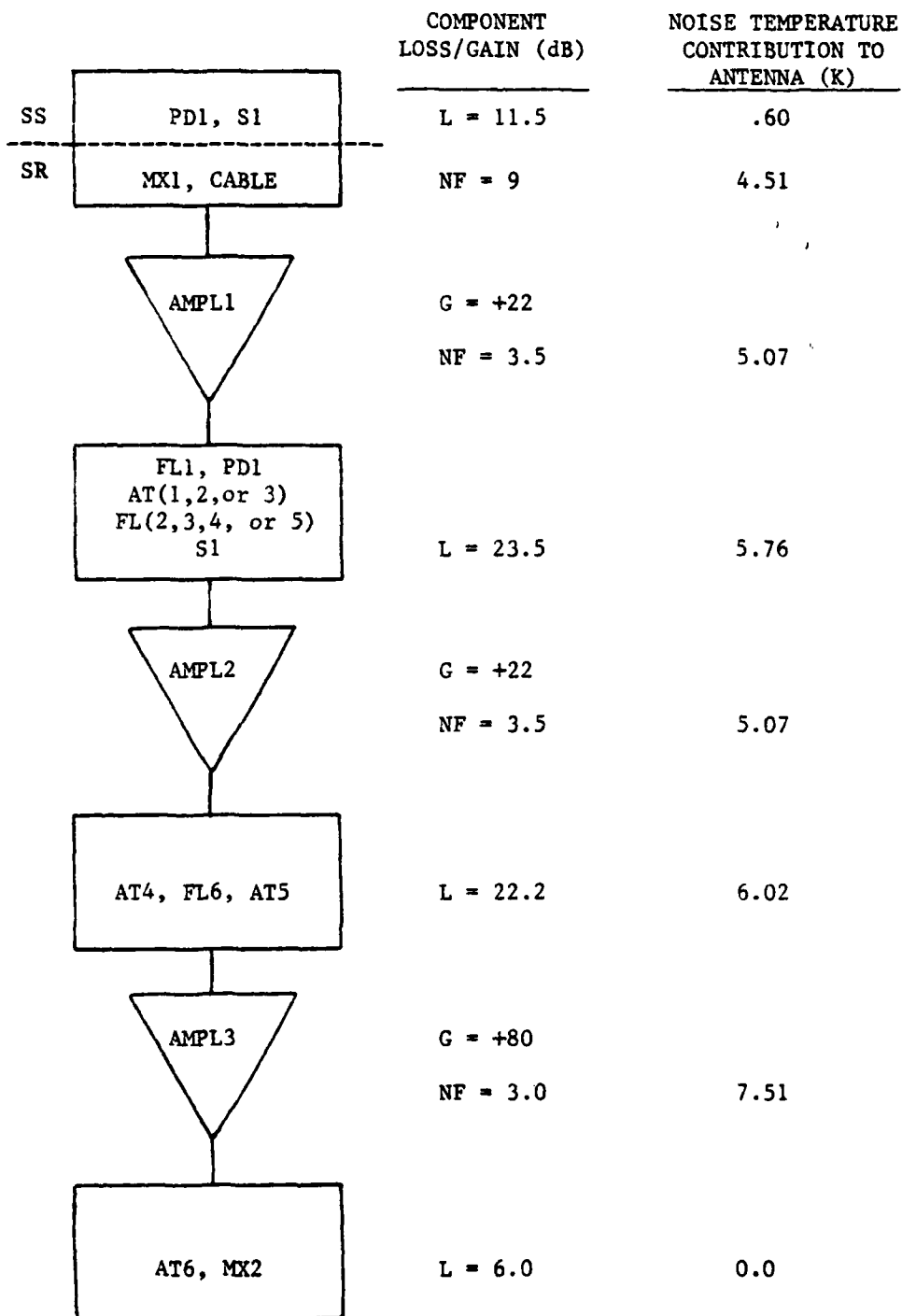


Figure 3.2
Noise Temperature Calculation Summary

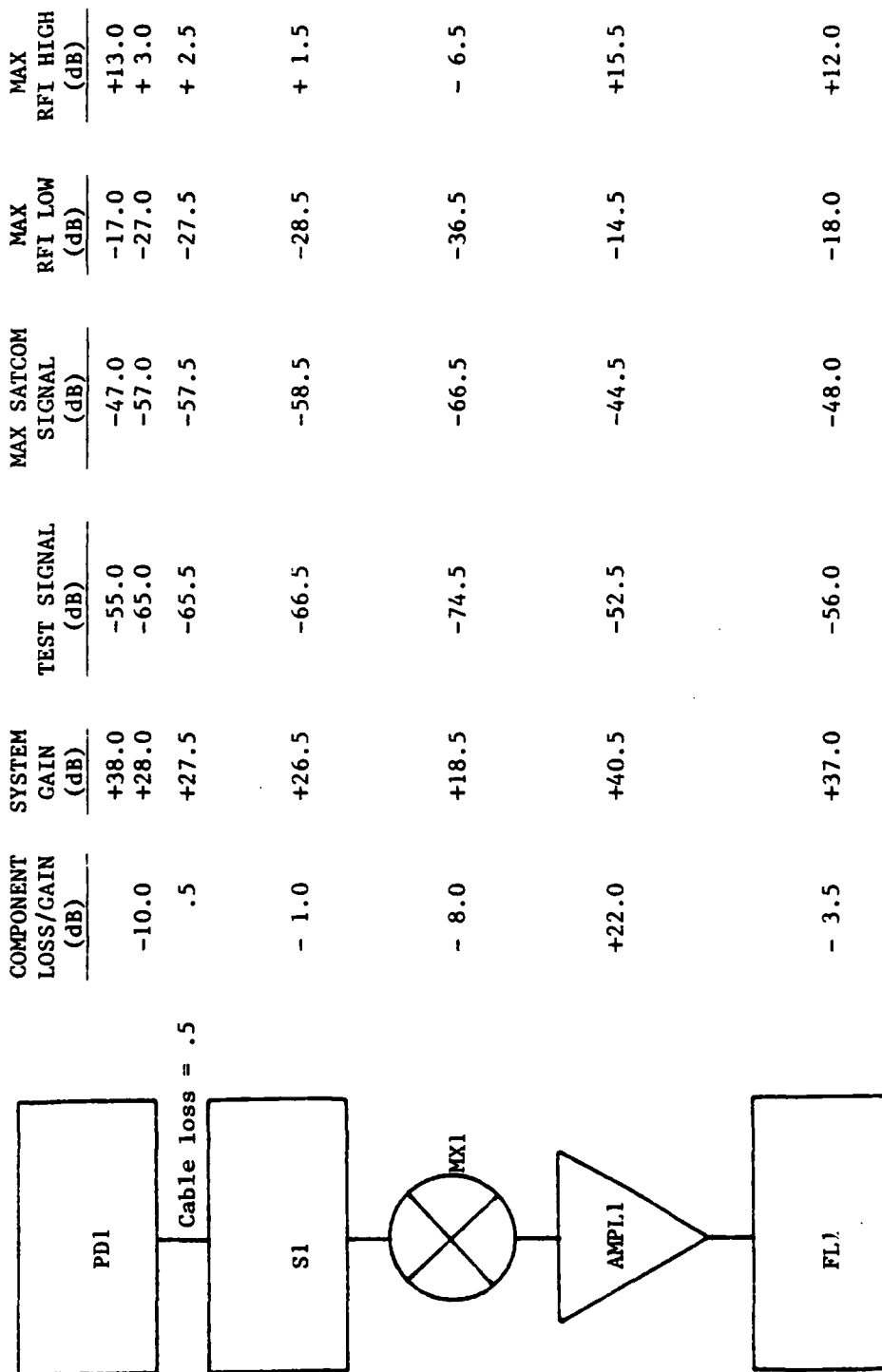


Figure 3.3 (Page 1 of 4)
Spectrum Receiver Signal Flow

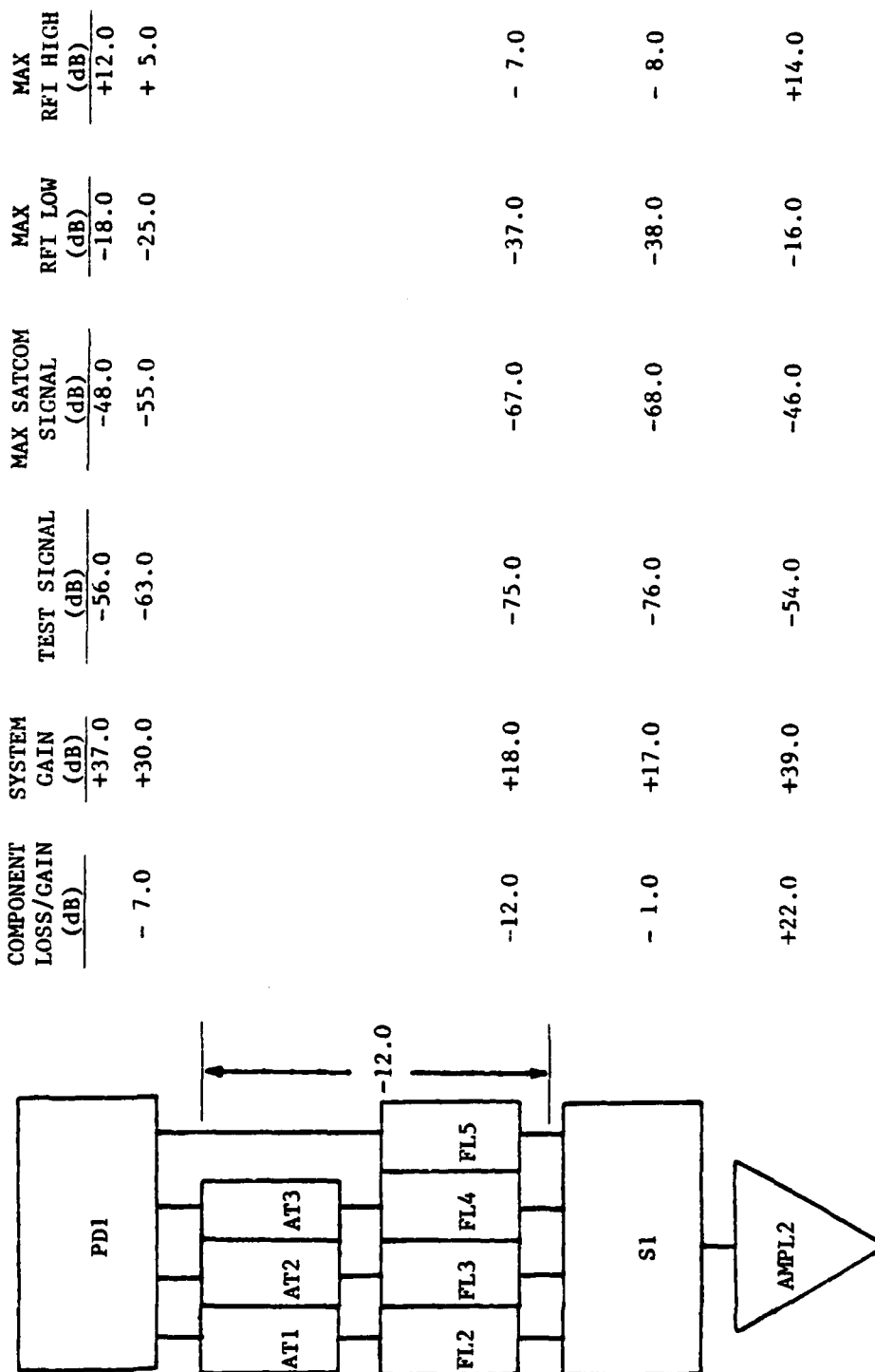
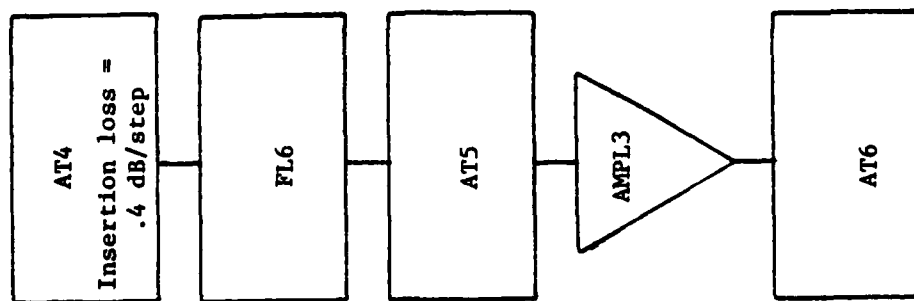
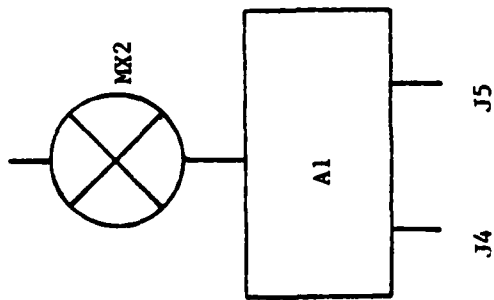


Figure 3.3 (Page 2 of 4)
Spectrum Receiver Signal Flow



COMPONENT LOSS/GAIN (dB)	SYSTEM GAIN (dB)	TEST SIGNAL (dB)	MAX SATCOM SIGNAL (dB)	MAX RFI LOW (dB)	MAX RFI HIGH (dB)
SATCOM RFI LOW RFI HIGH	+39.0	-54.0	-46.0	-16.0	+14.0
	+22.6	-70.4	-62.4	-64.8	-67.2
	- 0.7	-71.1	-63.1	-65.5	-67.9
- 5.1	+16.8	-76.2	-68.2	-70.1	-73.0
+80.0	+96.8	+ 3.8	+11.8	+ 9.9	+ 7.0
- 6.0	+90.8	- 2.2	+ 5.8	+ 3.9	+ 1.0

Figure 3.3 (Page 3 of 4)
Spectrum Receiver Signal Flow



COMPONENT LOSS/GAIN (dB)	SYSTEM GAIN (dB)	TEST SIGNAL (dB)	MAX SATCOM SIGNAL (dB)	MAX RFI LOW (dB)	MAX RFI HIGH (dB)
- 8.0	+90.8	- 2.2	+ 5.8	+3.9	+ 1.0
	+82.8	-10.2	- 2.2	- 4.1	- 7.0
+29.7	+112.5	+19.5	+27.5	+25.6	+22.7
OUTPUT VOLTAGE (vrms)		2.11	5.3	4.26	3.05

Figure 3.3 (Page 4 of 4)
Spectrum Receiver Signal Flow

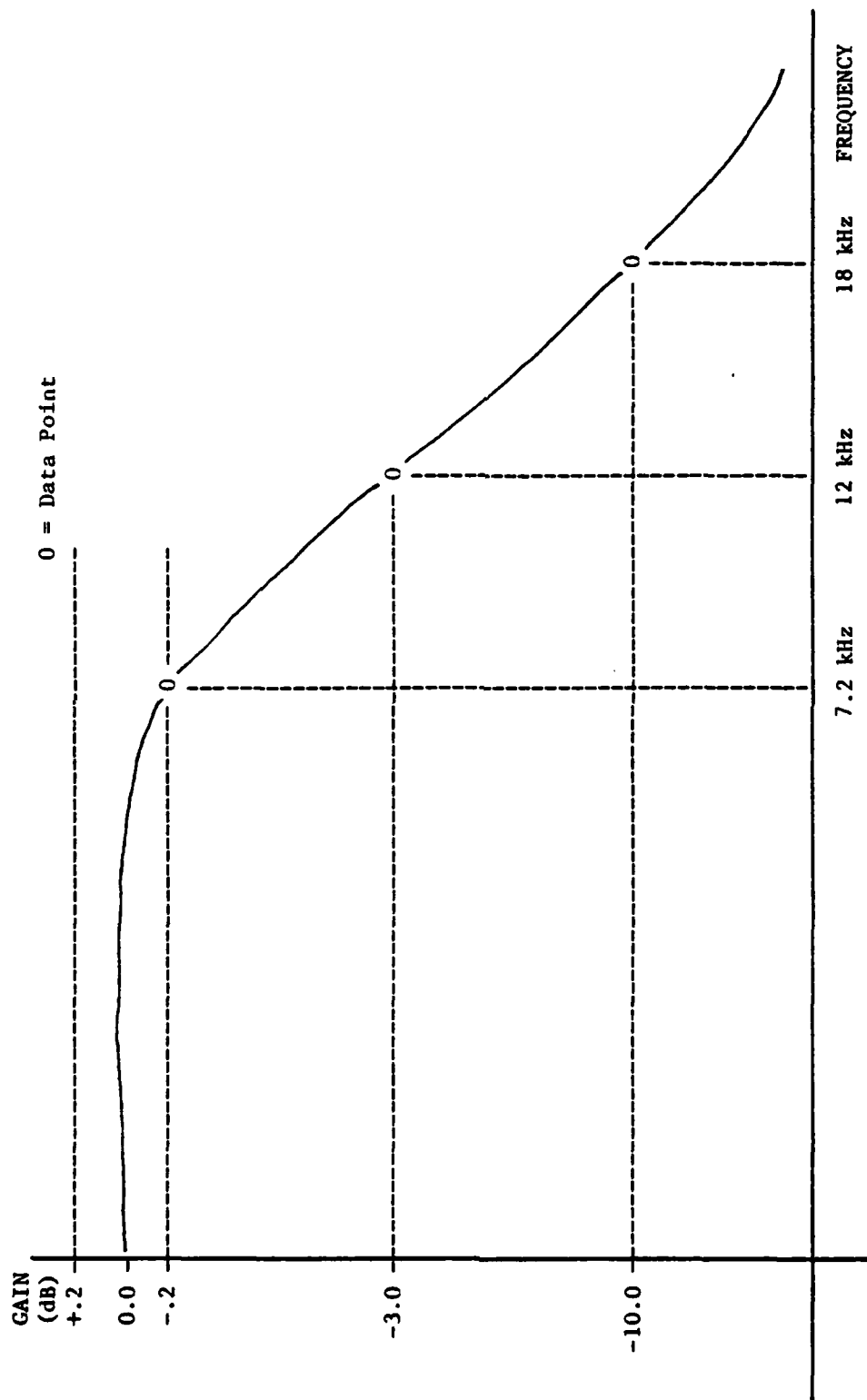


Figure 3.4
Spectrum Receiver Bandwidth 1 Lowpass Filter Characteristics

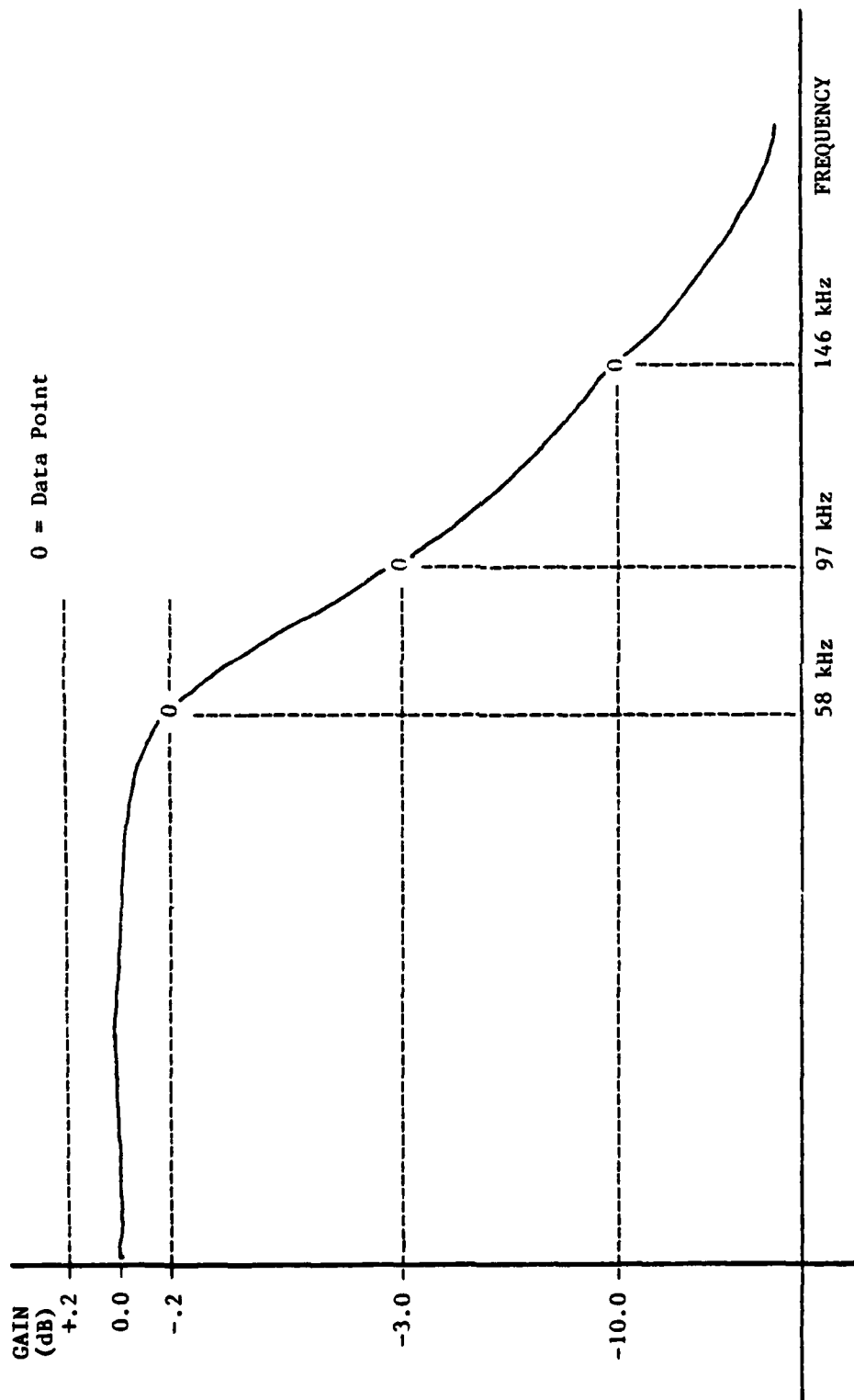


Figure 3.5
Spectrum Receiver Bandwidth 2 Lowpass Filter characteristics

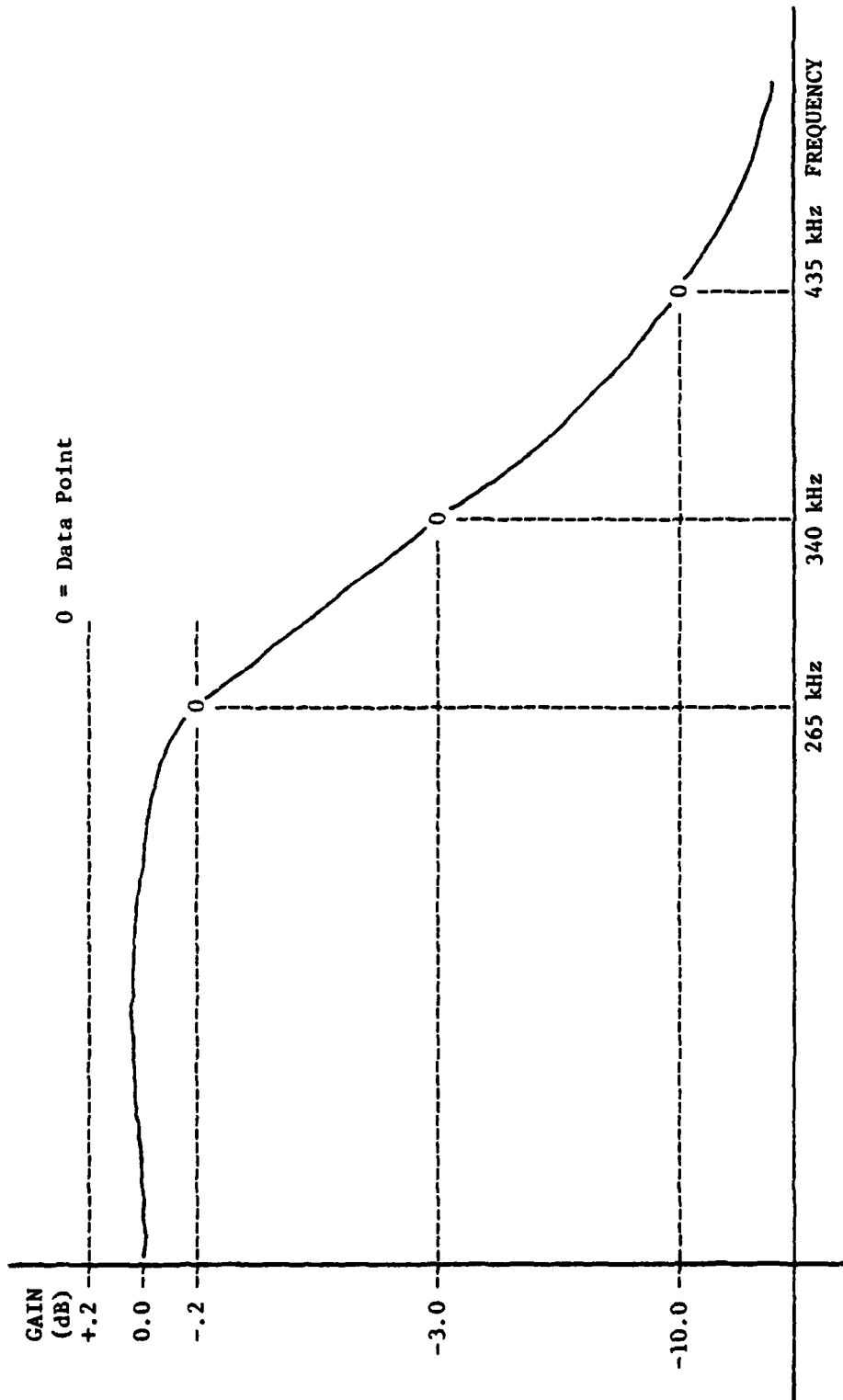


Figure 3.6
Spectrum Receiver Bandwidth 3 Lowpass Filter Characteristics

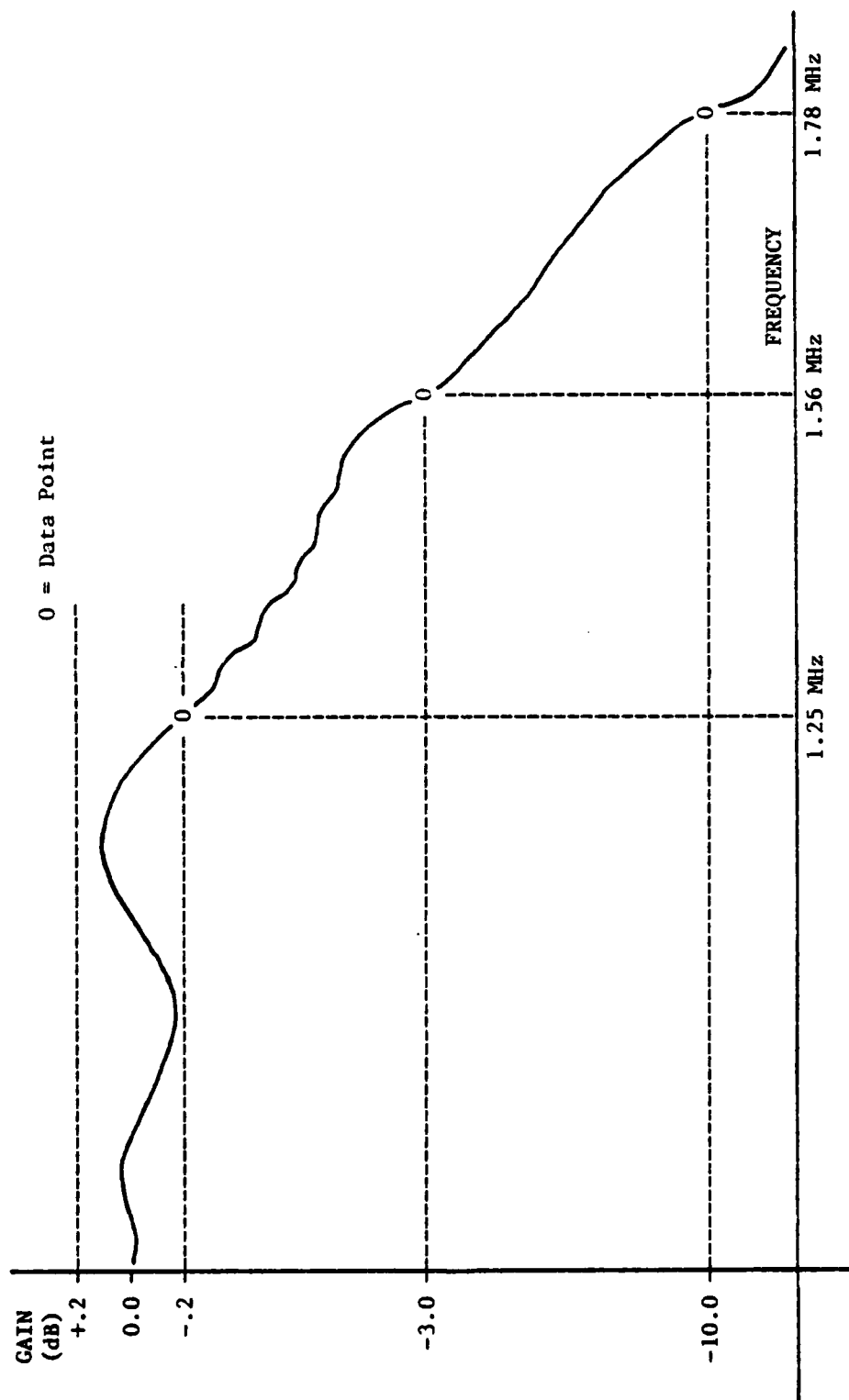


Figure 3.7
Spectrum Receiver Bandwidth 4 Lowpass Filter Characteristics

Observe:



Spectrum analyzer settings:

IF Bandwidth = 10 kHz

Scan Width = 20 kHz

Video Filter = 100 kHz

Scan Time = .1 sec.

Single Sweep, Storage

$$\text{SNR}_T = 20 \text{ dB} - 2.5 \text{ dB} = 17.5 \text{ dB} \quad \text{---} \quad 56.23$$

$$B = 12 \text{ kHz}$$

$$C = -85 \text{ dBm} \quad \text{---} \quad 3.162 \times 10^{-9} \text{ mW}$$

$$\text{SNR}_T = \frac{C}{N_o B} = \frac{3.162 \times 10^{-9} \text{ mW}}{N_o \times 12 \times 10^3} \quad \text{---} \quad 17.5 \text{ dB}$$

$$N_o = \frac{3.162 \times 10^{-9} \text{ mW}}{56.23 \times 12 \times 10^3} = 4.686 \times 10^{-15} = kT$$

$$T = T_{\text{GEN}} + T_{\text{RCVR}}$$

$$T = \frac{4.686 \times 10^{-15}}{1.38 \times 10^{-23} \times 10^3} \text{ K} = 3.396 \times 10^5 \text{ K}$$

$$T_{\text{GEN}} = 290 \text{ K}$$

$$T_{\text{RCVR}} = T - T_{\text{GEN}} = 3.3931 \times 10^5 \text{ K}$$

$$T_{\text{RCVR/ANT}} = \frac{T_{\text{RCVR}}}{\text{Gain from ANT to SS}}$$

$$\text{Gain from ANT to SS} = 38 \text{ dB} \quad \text{---} \quad 6.31 \times 10^3$$

$$T_{\text{RCVR/ANT}} = \frac{3.3931 \times 10^5}{6.31 \times 10^3} \text{ K} = 53.77 \text{ K}$$

Figure 3.8
Spectrum Receiver Noise Temperature Calculation

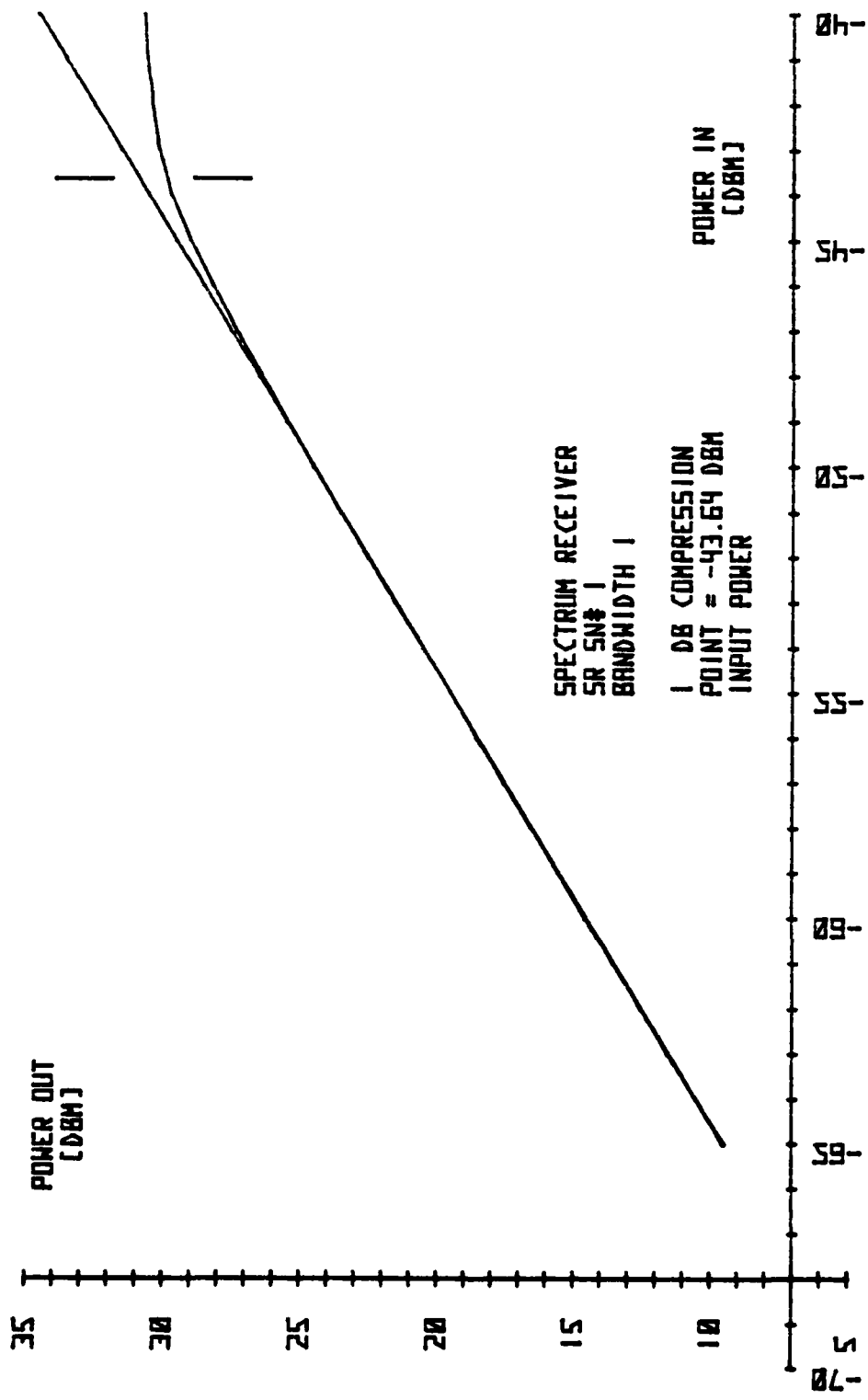


Figure 3.9
Spectrum Receiver Bandwidth 1 Power In vs. Power Out

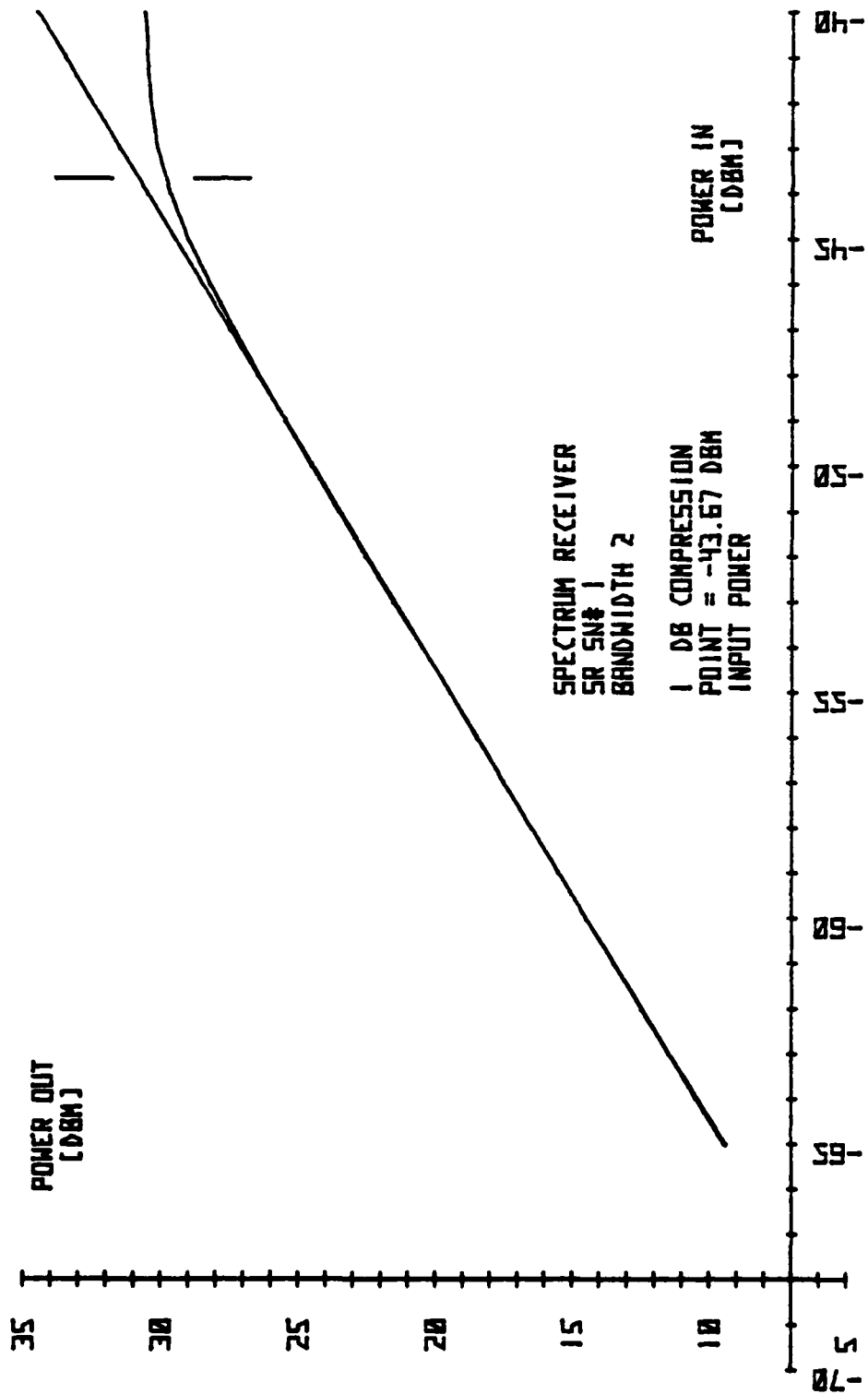


Figure 3.10
Spectrum Receiver Bandwidth 2 Power In vs. Power Out

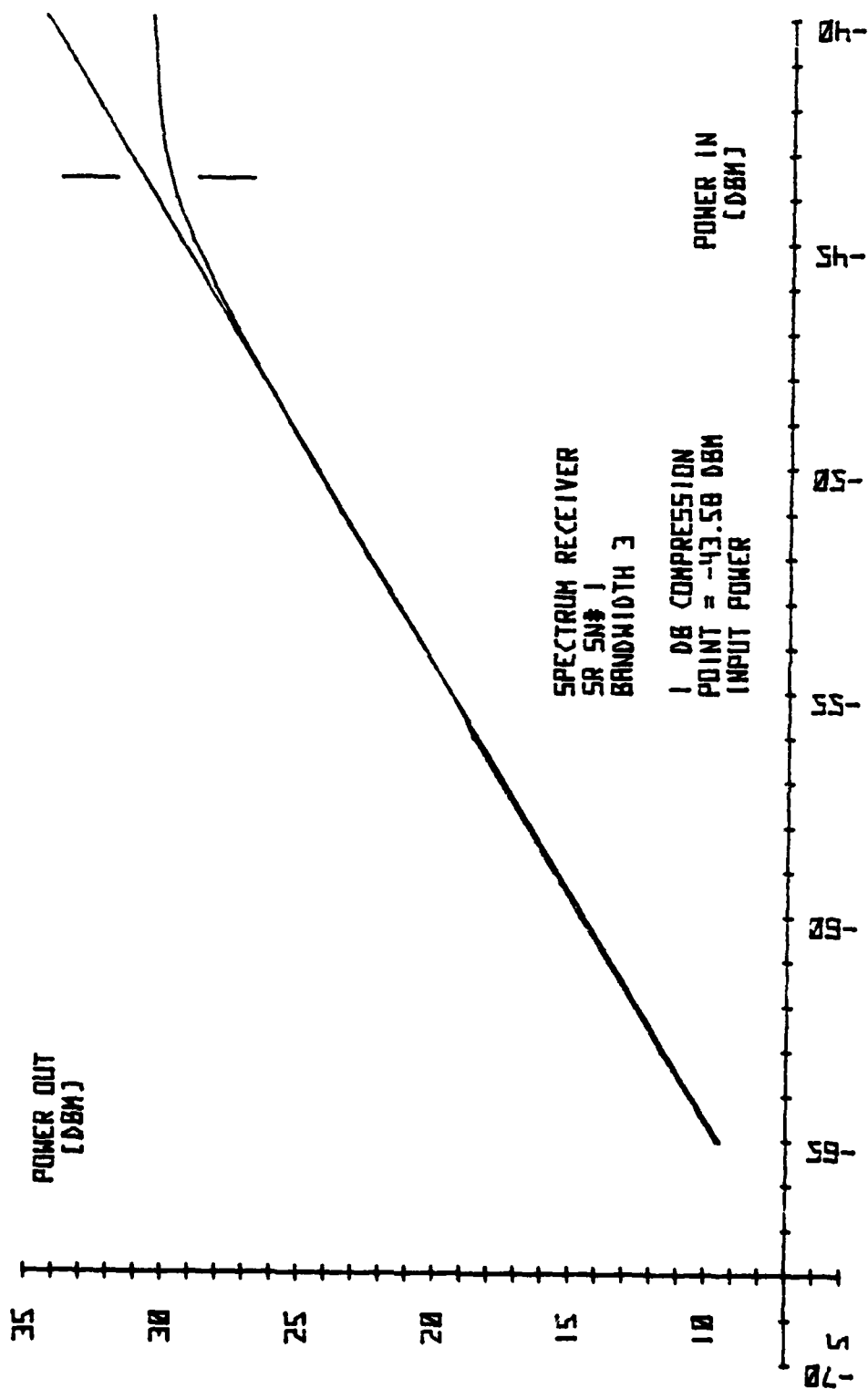


Figure 3.11
Spectrum Receiver Bandwidth 3 Power In vs. Power Out

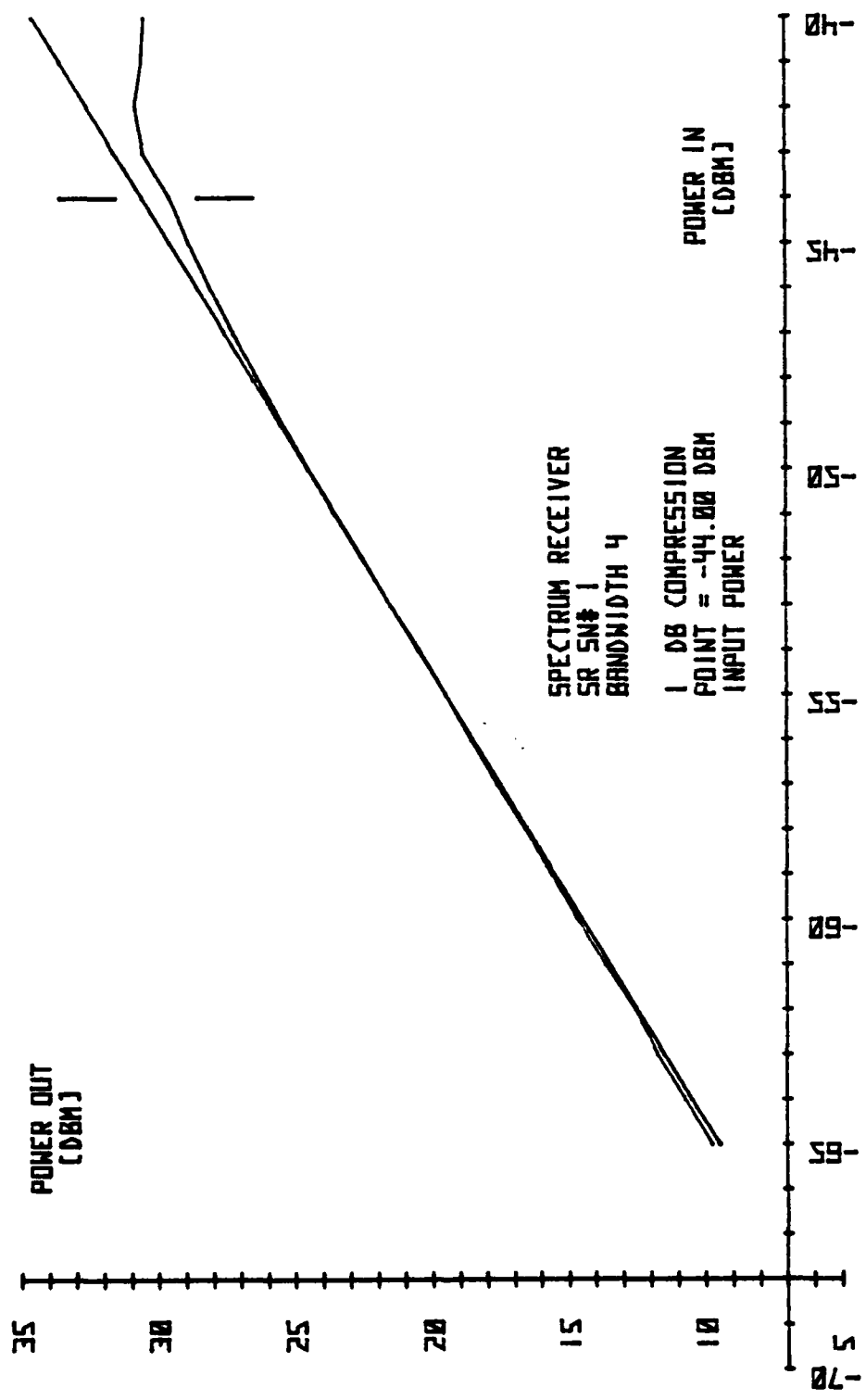


Figure 3.12
Spectrum Receiver Bandwidth 4 Power In vs. Power Out

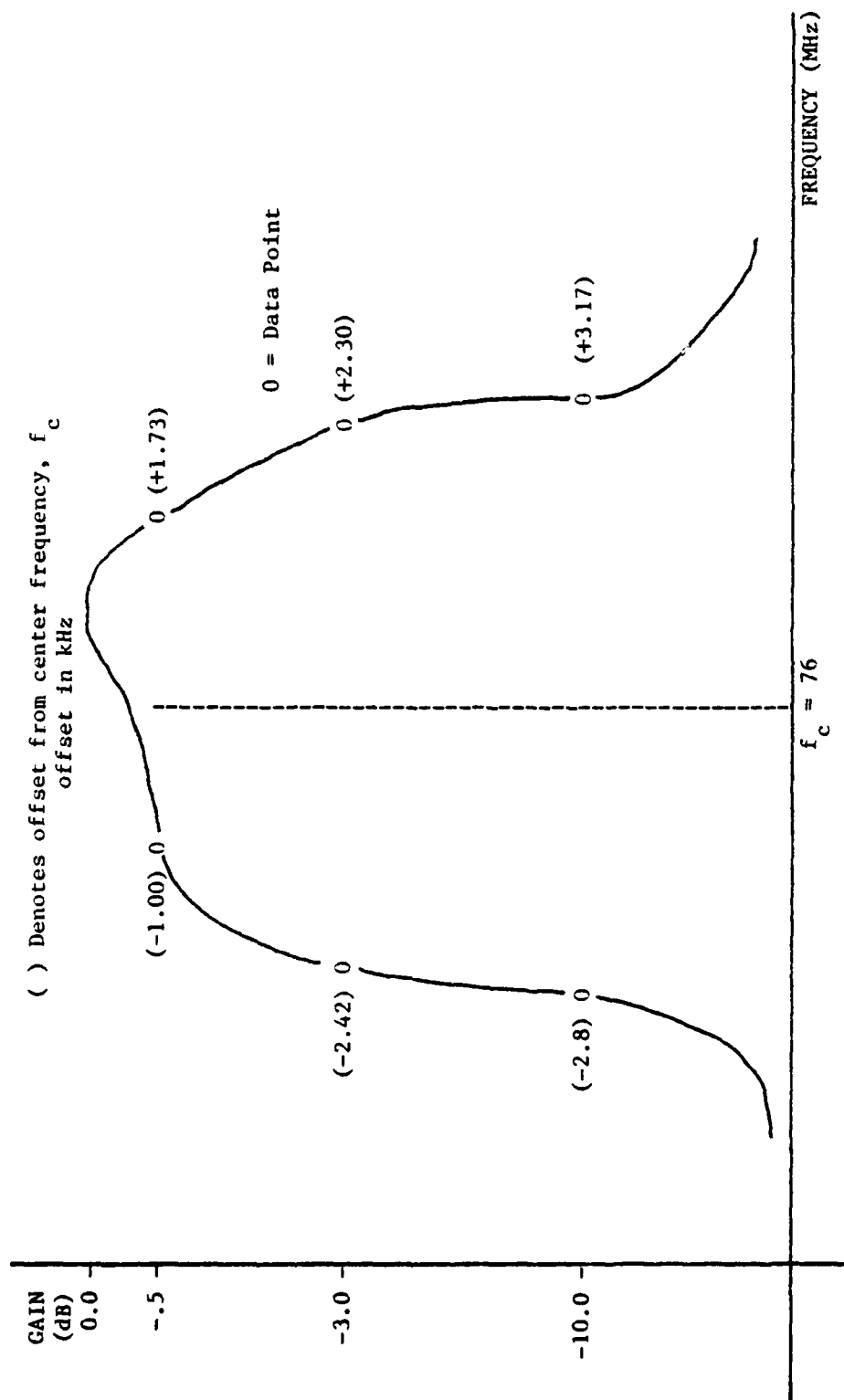


Figure 3.13
Spectrum Receiver Bandwidth 1 Frequency Response

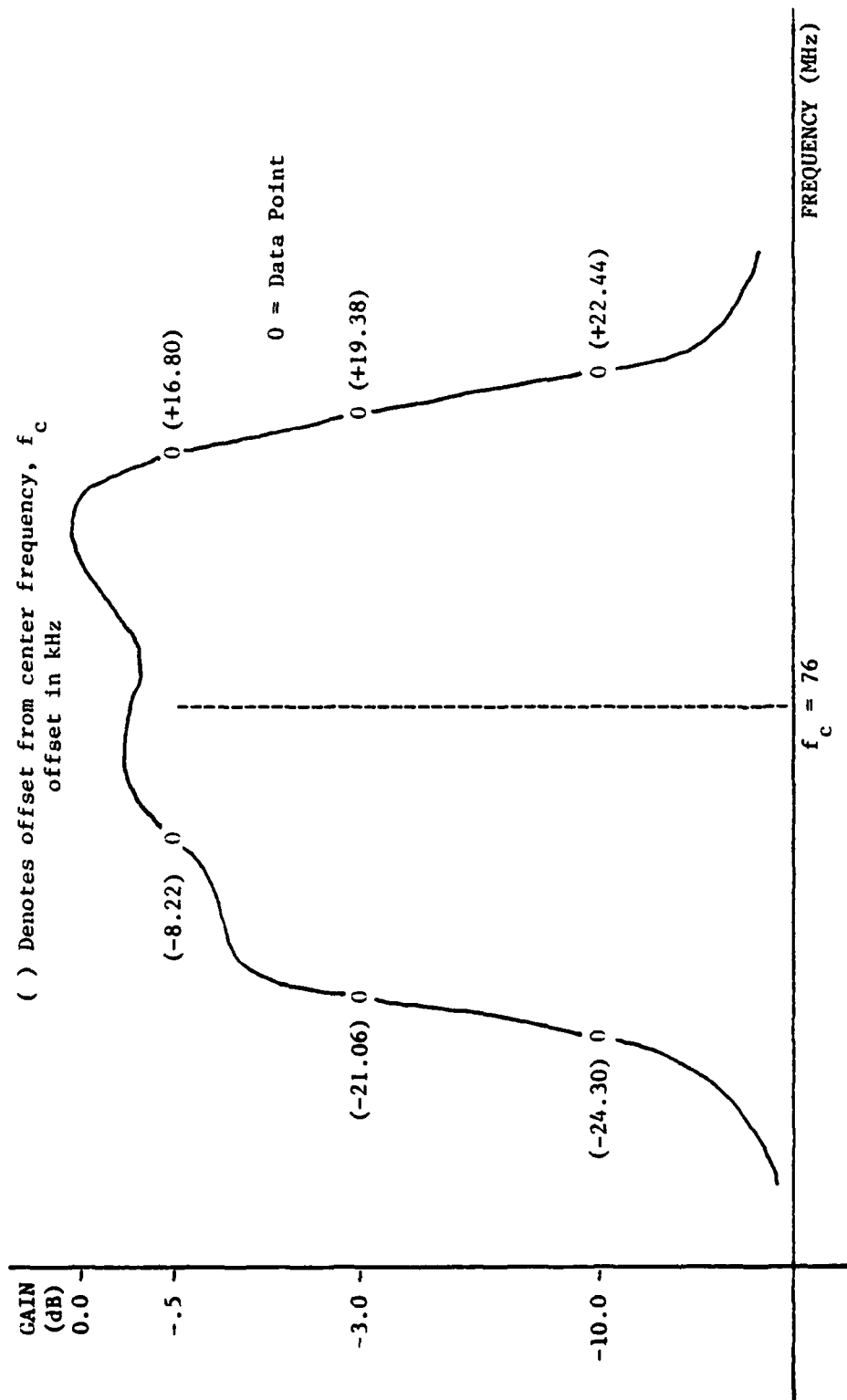


Figure 3.14
Spectrum Receiver Bandwidth 2 Frequency Response

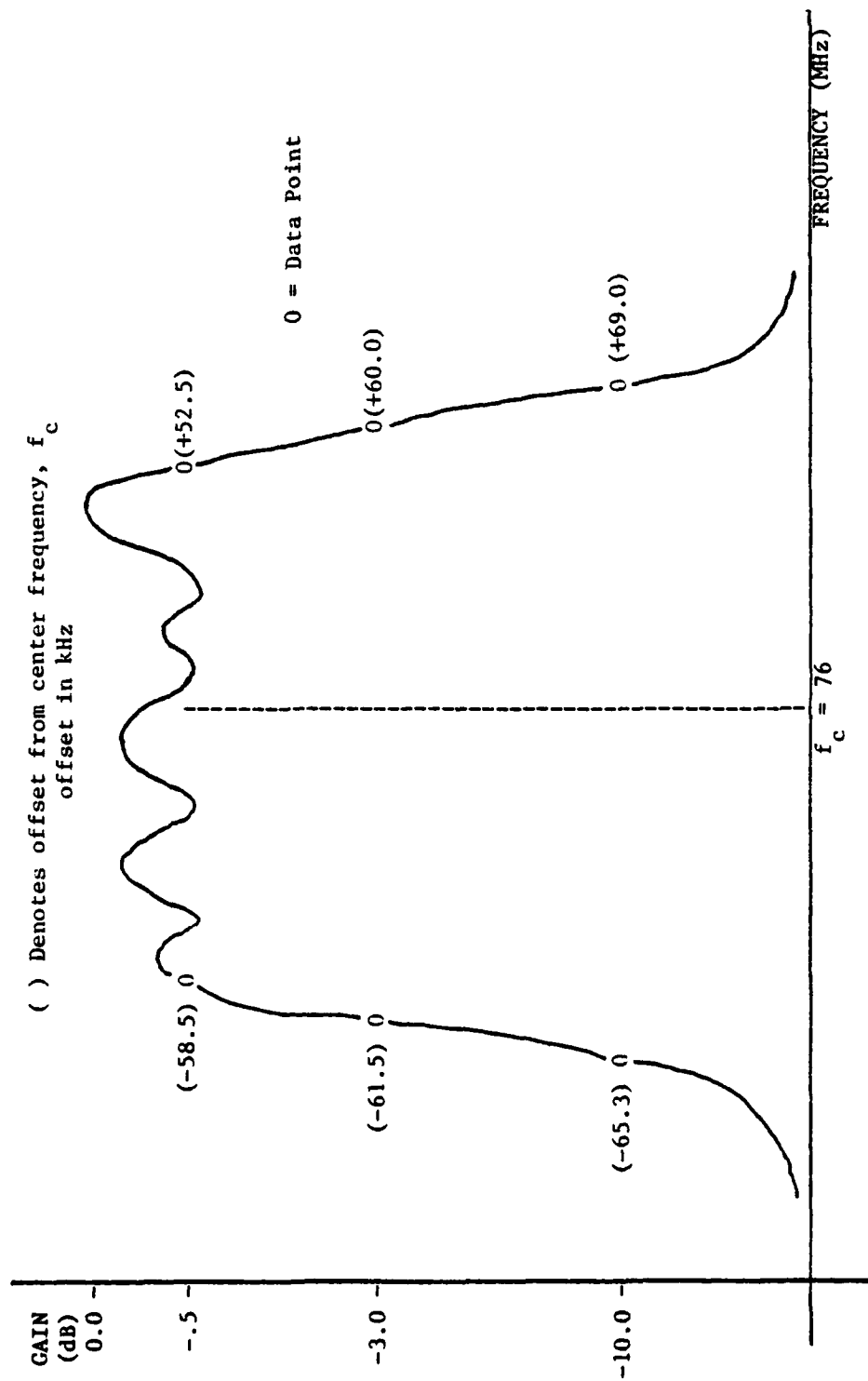


Figure 3.15
Spectrum Receiver Bandwidth 3 Frequency Response

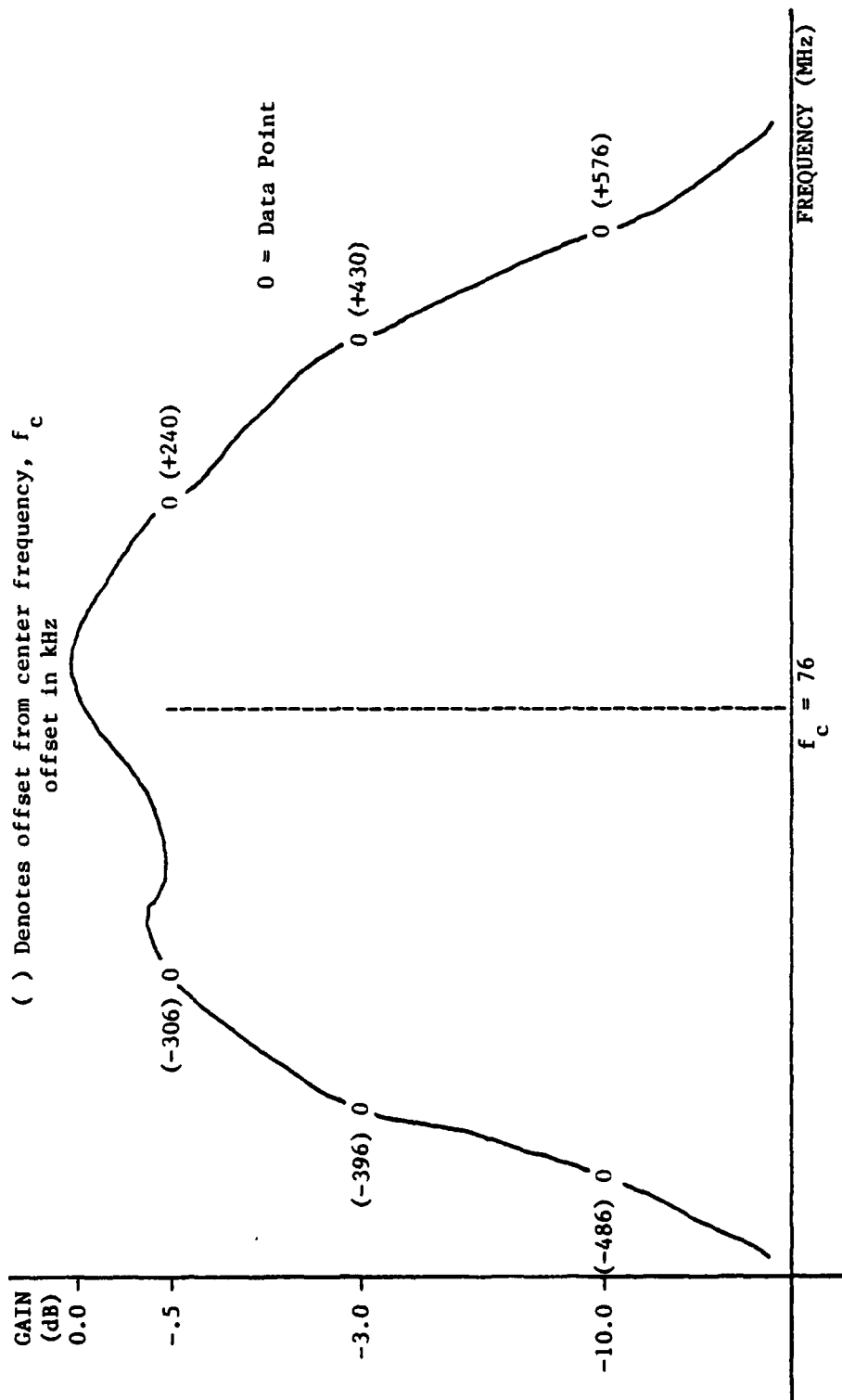


Figure 3.16
Spectrum Receiver Bandwidth 4 Frequency Response

IV. MENU CONTROL OF THE SSA

A. GENERAL

The menu concept was developed to optimize the interface between the operator and the SSA. Each menu is a combination of text and graphical representations of up to thirty five video "buttons" displayed to the operator on a HP2649A Display Terminal. A particular menu displayed to the operator provides information about the function selected, queries the operator regarding parameter changes, and allows the operator a means to indicate his response. In short, the menus were conceived to give the operator information, ask him questions about the system operation, and give him the answers. When the menu allows a selection or parameter change, buttons indicating the possible responses are drawn on the screen. The HP terminal uses reverse video to enhance a nominal "button" size of three characters high by six characters wide. This area is light relative to the surrounding area with text appearing as dark letters. The operator indicates his decision by "pushing" the button drawn on the screen. When the operator moves his finger toward the enhanced area, the position of his finger is sensed by a touch panel around the perimeter of the CRT. The position is transmitted to the CPU which stores for the current menu the X-Y location of each button and the function to be performed if the button is pressed.

The support software for menu operation and SSA control was developed previously and is documented in [3]. Since the publication of [3] the original software supporting the menu operation has been modified. Documentation for the new menu editor is located in the SSA Software Manual in the Satellite Communications Laboratory of the Naval Postgraduate School.

B. MENU TYPE

A total of 800 different menus may be stored on disk if a full disc is allocated. These menus are divided into four categories, two which provide an input/output arrangement for varying the system operating parameters, one to output the SSA status, and one to provide immediate documentation regarding the system operation. Menus which provide the input/output capability are labeled CONTROL and TASK. Those which provide the output information are called STATUS and HELP.

CONTROL menus concern system functions whose real-time operation is critical, such as the array processors' continuously producing output spectra. Software control for these functions is in the foreground and is always resident in core memory. Operating parameters are changed by modifying the parameter block associated with the specific module whose configuration is being changed.

TASK menus provide the interface for operations which are not time-critical. The collection of TASK menus operates many individual tasks or subroutines. Software subroutines are stored on disk and are transferred to the overlay area in core when called. Only one particular task may reside in core at one time. TASK menus appear the same as CONTROL menus on the screen; they differ only in the function they perform.

STATUS menus are used to retrieve and display the current SSA status. Current status includes information entered during the initialization phase, values entered to control the limits of operation, and values calculated by the normal system operation. For example, the operator may enter satellite names to appear on the large display screens. A list of satellites entered and the channel usage, also entered by the operator, may be viewed under the STATUS menus. Certain information may be gained by processing the satellite signals. The current calculated center frequency of a selected channel may be displayed on a STATUS menu as well as on one of the two screens.

HELP menus contain information about the SSA hardware, software, and operation in general. If required the operator may depart the currently displayed menu and transfer to the HELP series where he is immediately provided documentation on the menu he just left. This feature saves valuable time in that each non-HELP menu has a HELP menu keyed to it. The operator can get to a corresponding HELP menu with less than two menu changes.

C. DISPLAY TERMINAL CHARACTERISTICS

The terminal selected for menu display is the Hewlett Packard HP2649A. Any position on the five inch by ten inch screen may be determined by its row and column coordinates. The screen is 80 columns wide and 24 rows high. Columns 0 - 11 and rows 20 - 23 are used for the permanent display. The permanent display consists of 6 buttons: PRINT CRT1, PRINT CRT2, STATUS, CONTROL, HELP, and START TASK arranged vertically in columns 3 - 8 and an ACK MSG button to the right of the START TASK button. Rows 20 - 23 are used for the START TASK and ACK MSG buttons in addition to a space for messages to be displayed to the

operator. Figure 4.1 depicts the permanent buttons. The area not occupied by the permanent display is used for the menus. Menus are 68 columns wide by 20 rows high.

The terminal's microprocessor and set of control symbols allow the display of menus and the creation of the button effect. Table VII contains a list of the control symbols used by the HP2649A for menu display. Buttons are drawn using the reverse video mode where the raster becomes light and the characters become dark. Reverse video is done with either a half-bright screen or a full-bright screen. Using the two levels of brightness the terminal will provide feedback to the operator when he has pushed a button. For a normal button (3 rows high by 6 columns wide) the top and bottom rows will change brightness levels from half-bright to full-bright when pushed. The change in brightness is controlled by the computer in real time and is not a function of the image file for a particular menu.

In some cases emphasis may be added to certain parts of the menu by underlining or specifying one of the enhancement modes. Underlining is invoked by inserting the sequence ``&dD` before and ``&d@` after the text to be underlined. The half-bright, reverse video, enhancement mode is specified by inserting ``&dJ` before and ``&d@` after the text to be enhanced. Where the reverse video modes are required for menu generation, the control symbols are automatically inserted in the image file by the menu editor which will be discussed later. For text enhancement these symbols must be specified in the source file.

A special input system was adopted for entering responses to the menus. Input to the background monitor is via the Carroll Touch Input System which forms the outside border of the HP2649A screen area. The same software that generates the menu image also generates a set of coordinates corresponding to the position of the buttons drawn on the screen. This set of coordinates allows the computer to correlate the positional information sensed by the touch input system with the set of valid positions stored. If the operator were to press an area of the screen where no button was drawn an error message stating "Invalid input" would be displayed in the message area. Operation can continue but the message will not go away until it is acknowledged by pressing the ACK MSG button on the permanent display.

The use of the touch input system is advantageous in that it allows the operator to focus his attention on the menu display where information is being given to him. He may respond without redirecting his efforts to another input mechanism.

D. MENU CHARACTERISTICS

Each menu consists of (1) a title, (2) one to five blocks, and (3) zero to seven buttons per block. The title is placed on row 0 and occupies only one row. Blocks may vary in length according to need. Once a sketch has been made of the desired display it may be divided into parts at logical boundaries. For instance, if three questions each with four answers were asked, a logical dividing point would be between questions. Thus this hypothetical menu would contain three blocks and four buttons per block. Button size is normally 3 rows high by 6 columns wide. This is adequate space to label it with two lines of text each six characters long plus provide a one letter key equivalent whose function is to

provide a secondary means of interfacing with the computer. Should the touch input system around the perimeter of the display screen become inoperative, control of the SSA operation could be continued from the printer's keyboard. Instead of "pressing" the button on the HP terminal, the operator would identify the key equivalent of the button which indicates his response and type that letter on the keyboard. The computer stores the set of keyboard equivalents for the current menu and allows concurrent operation from the touch input system or from the keyboard.

Normally each block will contain text and several video buttons but may contain text or buttons. A maximum of seven buttons arranged one of three ways may be specified for each block. Buttons can be arranged in a row beside the text, in a row below the text, or in a column beside the text. The button format for each block is dependent on the menu as a whole in that a random arrangement of buttons for more than one block may cause buttons to overwrite each other and possibly parts of the text. Normally, buttons are arranged in a row beside the text.

E. MENU GENERATION

1. 'med', the Menu Editor

The function of the menu editor, 'med', is to transform the source file into an image file suitable for presentation on the HP2649A Display Terminal. It uses three files in the process of preparing the new image: (1) the menu source file, the plain text specification of the menu display, (2) 'mdir', the list of menus that have previously been processed by 'med' and those that are referred to by previously processed menus; and (3) 'menu', the output of the menu editor. In addition to the three files involved in the menu editing

process, 'med' provides a real-time diagnostics listing to the standard output which in most cases is the terminal where the editing process is being controlled. Samples of the diagnostic output listing are contained in Appendix O. One who is doing the editing can immediately see if the editor has located any errors. A synopsis of the editor inputs is also provided for information.

2. 'menuid.m', the Source File

Source files contain all information regarding the display and position of text and "buttons". Samples are contained in Appendix N. A standard format for the source file was adopted so that each line of text could be read and interpreted by a program called 'med', the menu editor. Basically the menu editor output is a set of image characters which determines the features displayed on the HP2649A terminal.

The menu source file consists of four lines of general information on as many text/question blocks that the menu will contain, ordered from the top to the bottom of the displayed menu. For each block of text the file must specify the text that is to appear, where the associated buttons (if any) are to appear, and the parameters which describe the button location and order. Buttons may be placed in a horizontal row beside or below the corresponding text or they may be placed in a vertical column to the right of the text.

The menu editor uses the menu source file as its input. It makes two passes through the text counting the number of blocks and buttons and formatting the output. In addition to preparing the set of image characters for the HP2649A it must extract two other types of data. First it removes the logging commands associated with each button. It

finally removes the action codes for the corresponding buttons. Table VIII contains the format for creating a proper source file.

3. 'mdir', the Menu Directory

'mdir' is used by med to keep track of all menus in the editing phase of preparation. Appendix Q is a sample 'mdir' listing. It is of use to the editor only in preparing the images; after the images have been transferred to RT-11 it is of no use. When the menu editor identifies the menu being processed, it goes to the directory 'mdir' to see if the menu has been processed before or if another menu referred to it. If either of these cases is true the editor will assign the menu the number corresponding to the text line number on which it appears in 'mdir'. For cases where a menu is not listed in the directory the editor looks for the first vacant line where it will write the menuid. Menuids may be deleted from the directory listing by processing a source file which contains the menuid on the first and only line. The editor will replace the menuid with '00' indicating a vacant line to the editor during future operations. If a vacant line is not found the editor will merely add the new menuid to the bottom of the directory listing. Many, in fact most, menus refer to several others which may be called as a response for a button pushed. The editor must also identify these menus by the three digit number obtained from 'mdir'. The number assigned to a menu image file is important in that it is used to determine the order the menus will be stored on disc for real-time operation.

4. 'menu', the Image File

The logging commands, the image characters, and the action codes with associated parameters are written by the menu editor into the file called 'menu'. Samples are contained in Appendix P. After each menu source file is processed by 'med', 'menu' must be transferred to another file name; otherwise, it will be written over when the next file is processed by the menu editor. In the preparation of the current set of menus, 'menu' was moved to a file of the form 'menuid.mu' (u specifies UNIX vice RT-11 which will be used later.) in a separate UNIX directory labelled 'usave'. 'usave' contains the set of menu images and options which will later be transferred to disc in a RT-11 compatible format for real-time control of the SSA. All software for the SSA is eventually converted to RT-11 operating system format for execution.

5. 'mview', the Display Program

'mview' is a recent addition to the support software library for generating and displaying menus. In the generation phase of menu preparation it is desirable to view the menus after the image file has been created. Immediately after the menu editor has produced the image file from the source file, the image may be located in the file called 'menu'. Before continuing with the editing process, the current output of the menu editor should be viewed to ensure the desired menu image was properly specified. The menu may be viewed under certain restrictions. Menu images can only be displayed on the HP2649A Display Terminal regardless of whether the image is being displayed under UNIX or RT-11. 'mview' operates under UNIX. Other programs discussed in a later section of this chapter allow display of the menu images on the CONRAC

video monitors. The command to produce the image from 'menu' is simply

% mview

The image portion of 'menu' is fed via a 1200 baud line to the device labeled tty1. The HP2649A Display Terminal must be connected to this line, and set for 1200 baud operation.

F. OPERATION

1. General

Menu generation and support software run under the UNIX operating system while the SSA operational software runs under the RT-11 real-time operating system. Once all of the menus have been processed by the menu editor and the image files have been transferred to their respective files in the usave directory, usave, as a directory with its set of files, is transferred to the SSA system disc. Each menu requires 3072 bytes of fixed length storage space. Transfer from the UNIX disc to the RT-11 disc is done with the following UNIX command:

% rtsave <UNIX filename> /dev/rrk5 <RT-11 filename>

Once the menus have been transferred to the system RT-11 disc used for menu operation, RK5, they must be placed in the proper order in a 3000 block (1 block = 512 bytes) space reserved for the menu image files. A RT-11 program called 'WAITER' will systematically place a specified menu in its proper place according to the menu number assigned from 'mdir' during the menu editing phase. The menu images will always occupy six blocks. Menu number 0 (always 'startmenu') will occupy block 0 through block 5. Menu number 1 will occupy blocks 6 through 11, etc. After the menus are stored in their proper place on the RT-11 system disc the SSA is ready for control from the operator's console.

When the system is initialized the permanent buttons and the 'startmenu' will be displayed. The operator may now proceed to initiate any action he wishes. Suppose the operator pushes CONTROL; a duplicate of 'startmenu' will be displayed. This means he wishes to modify the real-time operation of the system and he wishes to monitor spectrum, tabulate signal parameters, set up a frequency receiver to determine the signal's center frequency or to view the signal on the modulation display, or set up the AN/WSC-3 to demodulate a signal or to transmit. After making his decision the operator presses the desired response button and one of two things happens. If he chooses a function regarding the primary or secondary satellite displays, he will find that one of the two large screens has been modified to display the function requested. If he has selected one of the OTHER functions or a SINGLE CHANNEL function for the primary or secondary satellite, he will find that STARTMENU will be erased and another menu will take its place on the screen. The operator has another decision to make; and, as usual, all valid responses are displayed as buttons. After he has reached the point where he is satisfied with the system operation, the operator will most likely want to return to his starting point - the display of the permanent buttons and the 'startmenu'. He has two options: (1) Since he is in the CONTROL branch he may push the permanent button CONTROL, and he will immediately return to the starting point or (2) He may press PREV MENU to display the menu displayed immediately preceeding the one currently displayed. He repeats this sequence until he returns to the first CONTROL menu which is the duplicate of 'startmenu'. Although the first CONTROL menu is identical to the initial 'startmenu' it can be distinguished by noting the brightness of the permanent button labeled

CONTROL. If this button has two bright bands at the top and bottom, the version of 'startmenu' that is being displayed is the first menu in the CONTROL series. If the button is one brightness, the menu displayed is the initial menu. The first CONTROL menu does not have a PREV MENU button since the permanent button CONTROL performs the same function. By returning to the starting point using option (2) the operator is able to review the sequence which led him through the set-up routine. Along the way back to the starting point he may make additional modifications to processes he has previously started or modified.

If at anytime during the set-up procedure, help or more information is desired, the operator presses the permanent button HELP. This displays the initial HELP menu, 'help0'. By pressing the button labeled HELP NOW the operator sees a HELP menu which provides additional information about the last non-HELP menu displayed. He returns to the menu which required the additional information by pressing the permanent button HELP.

The operator may desire to know the status of the system before making a decision regarding a control function. He then pushes the permanent button labeled STATUS. Status0 will be displayed where he may proceed to select the status he desires to view. After viewing the desired STATUS menu the operator pushes permanent button STATUS to return to the last non-STATUS menu displayed.

The same procedure is followed to initiate a task. Once the permanent button START TASK has been selected it will stay lit indicating that a task (subroutine) has been called from the disc and is now in the overlay region of core. It is possible a task may take a long time to execute in which case the operator would not want to press the permanent button TASK to erase the TASK menus. He may press the permanent button indicating another type of menu he wishes to view. A task is in memory only when the permanent button START TASK is lit. The task will be returned to disc if START TASK is pressed when lit and will halt any operation in progress due to the task that was removed from core.

2. A Typical Sequence

A typical sequence of menus used in the operation of the Spectrum Receivers is contained in Appendix R. Figure R.1 is the STARTMENU. It is displayed when none of the permanent buttons are lit or as soon as the permanent button CONTROL is pressed to begin a CONTROL sequence of operations. From this menu the operator may select one of five functions for either the primary guard satellite or the secondary guard satellite and choose the screen for display. This menu also allows the operator to display functions for any one of the six possible satellites stored in system memory by pressing OTHER SATS. If the operator wishes to set-up or change the operation of either Frequency Receiver he pushes the appropriate button, FREQ RCVR 1 or FREQ RCVR 2. The button AN/WSC-3 allows the operator to control the operation of the AN/WSC-3. Transmit and receive functions are controlled in this branch. KILL will display another menu which provides the operator with immediate access to buttons he can use to terminate any signal being generated by the SSA. The

AN/WSC-3 transmitter and the receiver test signal can be stopped on the 'kill menu'.

Consider the case where the operator wants to observe the spectrum of any one of the system's six satellites. He presses the OTHER SATS button. 'ctrl001', Figure R.2, will be displayed. The operator selects the satellite he wishes to monitor. He could have also chosen any one of the antennas or tape playback, but doing so would not allow him to choose a specific channel on a future menu; only frequency selection is allowed for an antenna selection, and neither channel nor frequency selection is allowed for tape playback. The names of the satellites are filled in by the particular communication station when the system is installed and may be changed if the satellites in view change. If any one of the six satellites is chosen 'ctrl002', Figure R.3 is displayed. This menu allows the operator to choose which of the five functions he wishes to display for the chosen satellite. The button labeled SINGLE CHAN is the only function which will summon a succeeding menu. To observe the spectrum of a single channel the operator pushes SINGLE CHAN to display the menu used to select the particular channel to be observed. Figure R.4 is 'ctrl003', the menu which contains the FLTSATCOM Navy channel selection. It also contains a button labeled FREQ SELECT which allows selection of a specific frequency on another menu. If the operator wishes to view the spectrum of Navy channel 6 he pushes NAVY 6. Spectrum analysis of Navy channel 6 begins after the channel is selected. Default parameters are used to begin the analysis until the operator modifies them on the following menus. Pushing NAVY 6 causes the spectrum to appear on the chosen screen and calls the next menu, 'ctrl010', for display. Figure R.5 shows 'ctrl010'. It is

conceivable that functions on this menu will not be necessary if the operator is satisfied with the spectrum display. The spectrum display is operating with the following default parameters: downlink; display bandwidth (kHz) = 30; frequency offset = no offset; downlink receive mode = NORMAL SATCOM. Parameters may be changed on this menu to suit the situation. Additional operating parameters may be changed on the next menu. To display 'ctrl011', press MODIFY. Figure R.6 is a representation of 'ctrl011'. The system is operating with the following default parameters: normal; resolution = medium (512 point FFT); averaging = normal (50 blocks of data per display cycle). Once the operator has reached this point in the menu sequence he may immediately depart the CONTROL branch by pressing the permanent button CONTROL or he may return to the starting point by reversing the menu sequence. By pressing PREV MENU on 'ctrl011' and each menu that follows he will eventually return to the starting point.

G. BACKUP OPERATION

In the event of a failure of either the HP2649A Display Terminal or the Carroll Input Touch System, backup modes of operation are available. Operation of the SSA may be continued on a backup basis using other system resources to perform the functions of the terminal and the input system. Should the display fail, the operator may divert the menu display to one of the large video monitors. Upon doing so the touch input system would be disabled and the operator would indicate his choice of button to be pushed by pressing the key on the keyboard which corresponds to the button's keyboard equivalent. Each button has a keyboard equivalent located in the bottom right hand corner. If the response to the indicated choice is a new menu, it will be displayed on

the same large screen monitor. Menus will continue to be displayed in the backup mode until the display terminal has been repaired. When the menus are again displayed on the display terminal, the keyboard equivalent may still be used to input instructions to the system via the keyboard; however, the recommended method is to use the touch input system.

The computer program 'gpmenu' is the software which controls the menu display on the large screen video monitors. 'gpmenu' operates on the menu called by the menu manager. Prior to display it removes all of the control character sequences from the image file and determines which function is to be performed. The control sequences which were direct commands to the display terminal become either a series of instructions or subroutine parameters for the graphics processors. For example, the control sequence '&dD would denote the beginning of an underlined portion of text. The display terminal would underline the characters following this sequence until the control sequence '&d@ was encountered. Underlining on the large screens is done by drawing a vector. Therefore, to convert the character sequence which underlines on the display terminal to subroutine parameters, the program has to store the current row and column where the start underline sequence was detected. It next stores the row and column where the stop underline sequence was detected. At this point the program converts the row and column information used for the display terminal into the equivalent pixel location to be passed to the subroutine 'vector'. Table VII will be helpful in understanding the operation of the program 'gpmenu'.

TABLE VII
CONTROL SYMBOLS USED BY THE HP2649A

<u>Symbols</u>	<u>Function</u>
\	Tab
~	ENQ/wait for acknowledge
^	End of image
~B	Advance one row (line feed)
~A	Reverse one row
~K	Erase to the end of the line
~1	Sets tabs at current column
~3	Clears tabs
~&dD	Begin underlining at current position
~&dJ	Half-bright reverse video
~&dB	Full-bright reverse video
~&d@	End reverse video mode
	End underlining
~&a	Position information to follow
Format of position which follows ~&a sequence: YYrXXC where YY = row number XX = column number	

Position sequence will appear as ~&a03r12C.

Special Symbol Used by Software in Real-time Operation

__(underline) Status fillin

TABLE VIII
MENU SOURCE FILE FORMAT

The following is a listing of the menu source file format. Input lines are indented for ease in understanding the order and arrangement. In the actual source file all input lines will be left justified.

1. Menuid (a 10 character name uniquely naming each menu)
2. Menu header (or title, may be up to 68 characters long)
3. Menu type (2 characters) plus
(optional) status block (1 character)

Menu type codes: co = CONTROL
 ta = TASK
 st = STATUS
 he = HELP
 ca = CALL

Status block codes start with ASCII '1' and continue for as many ASCII characters as there are blocks of status fill-ins.

4. Menuid of predecessor (a 10 character name)
5. Text for the block (up to 19 lines of 68 characters each)
A block may have no text in which case this line will not exist.
6.] (signifies the end of text or no text)
7. Block code (one of the following:

 r = button row beside text
 c = button column beside text
 b = button row below text
 0 = no buttons

8. The button label code, ll, followed by the button label. The label may appear on two lines within the button area. Each line may be a maximum of six characters long. Should a two line label be specified, the lines will be separated by a tilde, '~'.

9. The single character keyboard equivalent. This character will appear in the lower right hand corner of the button.
10. The 10 character logging command. A mnemonic which briefly describes the action of the button should be listed here. If the button is pressed the logging command is stored on disc for later retrieval to reconstruct system operation.
11. Action code. Two entries on successive lines are possible here, (1) a menu change or (2) a value to be returned to the program.

Menu change codes:

- dm menuid = display menu named menuid
- tm menuid = display a menu relative to menu named menuid, based on satellite type.
- sm = display stacked menu, i.e. the one which called the current menu
- xm = display the HELP documentation menu for the most recently displayed nonHELP menu

Codes for returning values to the program*

- ca number = call task whose number is given
- pb number = pass this number to the parameter block manager for control change
- nr number = return this number to the task currently in core
- ch character = return a single character to the task currently in core

.
.
Lines 8 through 11 may be repeated to give a total of seven buttons per block.
.
.

N. @ This character signifies the end of the block.

.
.
Lines 5 through N may be repeated to give a total of five blocks. Each block may have up to seven buttons.
.
.

The input source file ends with the end of block character, @, for the last block.



Figure 4.1
Menu Display - Permanent Buttons

V. CONCLUSIONS

The hardware presented in this report has been constructed according to the stated design parameters and thoroughly tested under laboratory conditions. After verification of the design specifications the Signal Selector was installed in the SSA. With the installation of the SS the computer was able to select a source for any of the system's seven receivers and downlink IF signals were provided to the Test Unit. At present there is no replacement module for the Signal Selector. If trouble develops, specific software tasks may be used to localize the problem and parts will have to be replaced on the currently installed module. In a six month period this module experienced two failures of the SP6T RF switches. Future plans should address a possible ready spare for the entire SS.

The awkward selection of the uplink signal XC3 and the tape playback should be considered in the next design review. This problem could be alleviated by separately providing each source to all of the receivers and increasing the number of ports on the source selection switches to accommodate seven inputs (three downlink, three uplink, and a tape playback). This idea could also be extended to the Frequency Receivers and the AN/WSC-3's inputs. It is conceivable that one would want to monitor uplink signals with the Frequency Receivers or the AN/WSC-3.

The design specifications of the Spectrum Receivers have been verified and four SRs have been installed in the SSA. Each of the Spectrum Receivers has been tested under laboratory conditions and the four in

the SSA are operating according to specifications. A total of six Spectrum Receivers were built; four were integrated into the SSA; one is a system spare; and one will be available in the laboratory for future testing, analysis, and design review.

Menu operation of the SSA has proven very successful. Having the touch panel as the input device has simplified system control and has allowed the operator to focus his attention on the display terminal where information is being presented. Backup display of the menus on the CONRAC video monitor has been successfully demonstrated.

Overall, the SSA will accomplish the goals set forth in the initial design. Software is currently available to provide real-time analysis of downlink and uplink satellite signals, and future software developments will vastly increase the analytical capabilities of the system.

APPENDIX A
COMPUTER CONTROL

The majority of the major modules comprising the SSA are controlled by the PDP-11/34 via the Control Bus Latch (CBL) boards. For the computer to direct control information to a particular device it must format the output data word into a form which can be interpreted by the Control Bus Driver (CBD) board. When the CBD board receives the DR-11C (parallel output interface) output it decodes the 16 bits as follows:

Bit 0 (LSB) :	A0	(LSB) Byte Number
1 :	A1	Byte Number
2 :	S0	(LSB) CBL Number
3 :	S1	CBL Number
4 :	S2	CBL Number
5 :	S3	CBL Number
6 :	x	Always zero
7 :	x	Always zero
8 :	D0	(LSB) Data
9 :	D1	Data
10 :	D2	Data
11 :	D3	Data
12 :	D4	Data
13 :	D5	Data
14 :	D6	Data
15 :	D7	Data

After the CBD receives the data word it extracts the above information and decides where to pass the eight data bits. It is the eight data bits which will ultimately control the SSA modules.

Example 1: The CBD receives the octal word 157416.

The equivalent binary word is 1101111100001110.

The Control Bus interprets the data as follows:

Byte # = 10
CBL # = 0011
Data = 11011111

The Control Bus then passes the data
byte 11011111 to byte 2 on CBL3.

In some cases four successive output operations must be performed by the computer to completely specify an operation as for the local oscillator frequency in Example 2 below.

Using the bit mapping for the Signal Selector, the local oscillators, and the Spectrum Receivers as a guide the receiver chains may be set up as follows.

Example 2:

Given: Set up Spectrum Receiver #1 to receive a downlink signal on 250.450 MHz from antenna #1. Spectrum Receiver programmable attenuation should be 16 dB for reception of a normal SATCOM signal. Display bandwidth is 30 kHz.

Find: the computer control sequence.

Solution: The computer will receive the above specifications from an operator who is making selections on an appropriate menu.

1. Construct the code to select the signal path from antenna 1 to SR1.
 - a. CBL for control of SS is CBL9.
 - b. Byte to control input to SR1 is byte 0.
 - c. D0 is active to select RC1 (antenna 1 downlink) for SR1.
 - d. Load byte 0 of CBL9 with 00000001.
16 bit data word = 0000000100100100.
Octal equivalent = 000444.

2. Construct the code for the local oscillator.
 - a. SK1 implies LO1.
 - b. It takes four steps to completely specify the LO frequency. One step is required to load each byte of the CBL.
 - c. From the formula for downlink signals, LO frequency would be 100.416 MHz.
 - d. Construct the four 16 bit data words to control the LO.
 - (1.) Load byte 0 of CBL1 with 100.
16 bit word = 1010000000000100
Octal equivalent = 120004
 - (2.) Load byte 1 of CBL1 with 41
16 bit word = 0100000100000101
Octal equivalent = 040405
 - (3.) Load byte 2 of CBL2 with 60.
16 bit word = 01100000000001010
Octal equivalent = 060012
 - (4.) load byte 3 of CBL1 with 00.
16 bit word = 0000000000000111
Octal equivalent = 000007
3. Construct the code for the SR attenuation and Bandwidth.
 - a. CBL for SR1 (2, 3, and 4) is CBL14.
 - b. Byte for SR1 is byte 0.
 - c. Construct the 16 bit word to control SR1.
 - (1.) D7, D6, D5, D4 control bandwidth selection according to Table IV. To select 30 kHz bandwidth D5 is active (=1).
 - (2.) D3, D2, D1, D0 control attenuation selection according to Table IV. To select 16 dB attenuation D1 is active (=1).
 - (3.) Load byte 0 of CBL14 with 00100010.
16 bit word = 0010001000111000.
Octal equivalent = 021070.

The computer control sequence must be equivalent to the following RT-11 assembly language instructions:

```

MOV #000444, 167772 ; SS: RC1 = input to SR1
MOV #120004, 167772 ; L01: MHz = 100.xxx xxx
MOV #040405, 167772 ; L01: kHz (100's 10's) = xxx.41x xxx
MOV #060012, 167772 ; L01: kHz (1's), Hz (100's) = xxx.xx6 0xx
MOV #000007, 167772 ; L01: Hz(10's 1's) = xxx.xxx x00
MOV #021070, 167772 ; SR1: Attenuation = 16dB, BW = 30 kHz

```

AD-A097 532

NAVAL POSTGRADUATE SCHOOL MONTEREY CA
SIGNAL SELECTOR, SPECTRUM RECEIVERS AND TOUCH PANEL CONTROL FOR--ETC(U)
JUN 80 D R GAMBLE, J E OHLSON

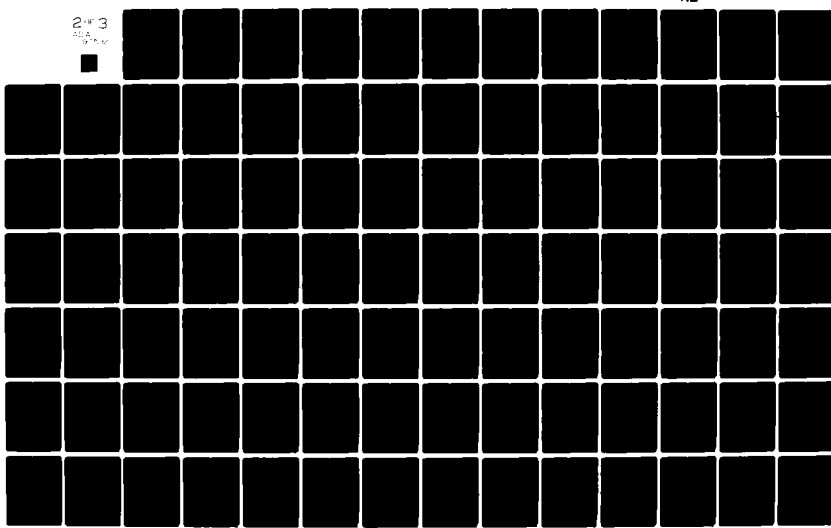
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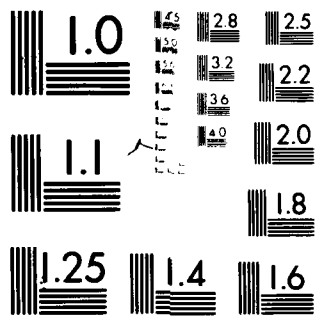
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MICROCOPY RESOLUTION TEST CHART

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APPENDIX B

SIGNAL SELECTOR (SS) CONNECTOR PINOUTS

A. SS-J18 4 pin power connector

<u>Pin</u>	<u>Function</u>	<u>In/out</u>
1	+5 v	In
2	+5 v return	
3	-5 v	In
4	-5 v return	

B. SS-J19 CBL9 Input

<u>Pin#</u>	<u>Byte</u>	<u>Bit</u>	<u>Function</u>	<u>In/Out</u>
1	2	4	SR3 select XC2	In
2	2	5	SR3 select XC3/AS	In
3	2	0	SR3 select RC1	In
4	2	1	SR3 select RC2	In
5	1	4	SR2 select XC2	In
6	1	5	SR2 select XC3/AS	In
7	1	0	SR2 select RC1	In
8	1	1	SR2 select RC2	In
9	0	4	SR1 select XC2	In
10	0	5	SR1 select XC3/AS	In
11	0	0	SR1 select RC2	In
12	0	1	SR1 select RC2	In
13	NA	NA	+5 v (NC)	In
14	NA	NA	+5 v (NC)	In
15	3	4	SR4 select XC2	In
16	3	5	SR4 select XC3/AS	In
17	3	0	SR4 select RC1	In
18	3	1	SR4 select RC2	In
19	3	2	SR4 select RC3	In
20	3	3	SR4 select XC1	In
21	NA	NA	Not used (NC)	
22	NA	NA	Not used (NC)	
23	NA	NA	+5 v (NC)	In
24	NA	NA	+5 v (NC)	In
25	NA	NA	+5 v (NC)	In
26	2	6	(NC)	In
27	2	7	(NC)	In
28	2	2	SR3 select RC3	In
29	2	3	SR3 select XC1	In
30	1	6	(NC)	In
31	1	7	(NC)	In
32	1	2	SR2 select RC3	In
33	1	3	SR2 select XC1	In
34	0	6	(NC)	In
35	0	7	(NC)	In

36	0	2	SR1 select RC3	In
37	0	3	SR1 select XC1	In
38	NA	NA	+5 v (NC)	In
39	NA	NA	+5 v (NC)	In
40	3	6	(NC)	In
41	3	7	(NC)	In
42	NA	NA	GND	
43	NA	NA	Enable 3 (NC)	In
44	NA	NA	Enable 2 (NC)	In
45	NA	NA	Enable 1 (NC)	In
46	NA	NA	+5 v (NC)	In
47	NA	NA	+5 v (NC)	In
48	NA	NA	Enable 0 (NC)	In
49	NA	NA	GND	
50	NA	NA	GND	

C. SS-J20 CBL10

<u>Pin</u>	<u>Byte</u>	<u>Bit</u>	<u>Function</u>	<u>In/out</u>
1	2	4	(NC)	In
2	2	5	FR1 select XC3/AS	In
3	2	0	FR1 select RC1	In
4	2	1	FR1 select RC2	In
5	1	4	(NC)	In
6	1	5	WP select XC3/AS	In
7	1	0	WP select RC1	In
8	1	1	WP select RC2	In
9	0	4	(NC)	In
10	0	5	(NC)	In
11	0	0	XC3 pre select	In
12	0	1	AS pre select	In
13	NA	NA	+5 v (NC)	In
14	NA	NA	+5 v (NC)	In
15	3	4	(NC)	In
16	3	5	FR2 select XC3/AS	In
17	3	0	FR2 select RC1	In
18	3	1	FR2 select RC2	In
19	3	2	FR2 select RC3	In
20	3	3	(NC)	In
21	NA	NA	Not used	
22	NA	NA	Not used	
23	NA	NA	+5 v (NC)	In
24	NA	NA	+5 v (NC)	In
25	NA	NA	+5 v (NC)	In
26	2	6	(NC)	In
27	2	7	(NC)	In
28	2	2	FR1 select RC3	In
29	2	3	(NC)	In
30	1	6	(NC)	In
31	1	7	(NC)	In
32	1	2	WP select RC3	In

33	1	3	(NC)	In
34	0	6	(NC)	In
35	0	7	(NC)	In
36	0	2	(NC)	In
37	0	3	(NC)	In
38	NA	NA	+5 v (NC)	In
39	NA	NA	+5 v (NC)	In
40	3	6	(NC)	In
41	3	7	(NC)	In
42	NA	NA	GND	
43	NA	NA	Enable 3 (NC)	In
44	NA	NA	Enable 2 (NC)	In
45	NA	NA	Enable 1 (NC)	In
46	NA	NA	+5 v (NC)	In
47	NA	NA	+5 v (NC)	In
48	NA	NA	Enable 0 (NC)	In
49	NA	NA	GND	
50	NA	NA	GND	

APPENDIX C

SIGNAL SELECTOR (SS) PARTS LIST

<u>SYMBOL</u>	<u>DESCRIPTION</u>
1. S1, S2, S3, S4	SP6T RF Switch, Lorch ES-393M
2. S5, S6, S7	SP4T RF Switch, Lorch ES-391M
3. S8	SPDT RF Switch, Lorch ES-387M
4. PD1, PD2, PD3, PD4	8 way power divider, Merrimac PDM-80-55
5. PD5, PD6	4 way power divider, Merrimac PDM-40-110
6. J18	MS3102A 14S-2P 4 pin power receptacle
7. J19, J20	50 pin microribbon receptacle Cinch 57-40500
8. AT1	50 ohm termination, Elcom CT-50
9. C1, C2	0.01 uF 1000 WVDC

APPENDIX D

SIGNAL SELECTOR (SS) COMPONENT SPECIFICATIONS

A. Coaxial Switch

1. Circuit symbol: S1, S2, S3, S4
2. Manufacturer: Lorch Electronics
3. Model: ES-393M
4. Specifications:

Configuration	SP6T
TTL compatible	active low
VSWR	1.5 : 1
Self terminating, unused port impedance	50 ohms
Insertion loss (max)	1 dB
Isolation (min)	70 dB
1 watt non-destruct frequency range	20 - 400 MHz
Switching time	10 microseconds
DC power required	+5 v at 195 ma -5 v at 175 ma

B. Coaxial Switch

1. Circuit symbol: S5, S6, S7
2. Manufacturer: Lorch Electronics
3. Model: ES-391M
4. Specifications:

Configuration	SP4T
TTL compatible	active low
VSWR	1.5 : 1
Self terminating, unused port impedance	50 ohms
Insertion loss (max)	1 dB
Isolation (min)	70 dB
1 watt non-destruct frequency range	20 - 400 MHz
Switching time	10 microseconds
DC power required (max)	+5 v at 170 ma -5 v at 150 ma

C. Coaxial Switch

1. Circuit symbol: S8
2. Manufacturer: Lorch Electronics
3. Model: ES-387M
4. Specifications:

Configuration	SPDT
TTL compatible	active low
VSWR	1.5 : 1
Self terminating, unused port impedance	50 ohms
Insertion loss (max)	1 dB
Isolation (min)	70 dB
1 watt non-destruct frequency range	20 - 400 MHz
Switching time	10 microseconds
DC power (max)	+5 v at 85 ma -5 v at 75 ma

D. 8 Way Power Divider

1. Circuit symbol: PD1, PD2, PD3, PD4
2. Manufacturer: Merrimac Industries
3. Model: PDM-80-55
4. Specification:

Frequency range	10 - 100 MHz
Theoretical loss	9 dB
Isolation	30 dB
Insertion loss	1 dB
Impedance	50 ohms
VSWR	1.5 : 1
Connectors	SMA female
Power (max)	5 watts

E. Power Divider

1. Circuit symbol: PD5, PD6
2. Manufacturer: Merrimac Industries
3. Model: PDM-40-110
4. Specification:

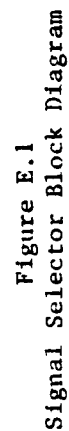
Frequency range	20 - 200 MHz
Theoretical loss	6 dB
Isolation	30 dB
Insertion loss	0.7 dB
Impedance	50 ohms
VSWR	1.3 : 1
Connectors	SMA female
Power (max)	2 watts

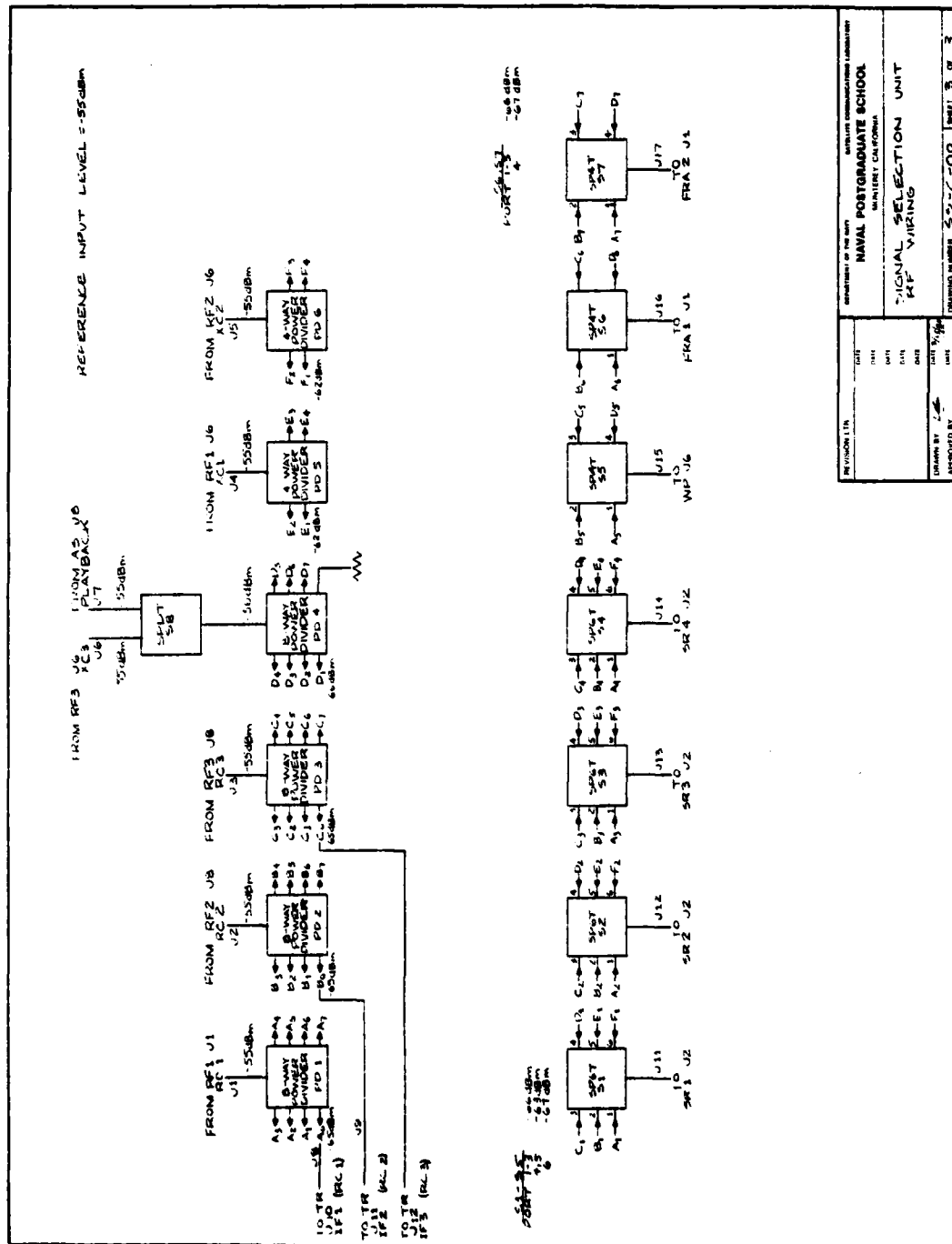
APPENDIX E

SIGNAL SELECTOR (SS) BLUEPRINTS

This appendix contains the blueprints necessary to construct the Signal Selector. The blueprints contained in the appendix are:

- | | | |
|----|---------|--------|
| 1. | SS-C-00 | 1 of 3 |
| 2. | SS-C-00 | 2 of 3 |
| 3. | SS-C-00 | 3 of 3 |
| 4. | SS-C-01 | 1 of 1 |
| 5. | SS-C-02 | 1 of 1 |





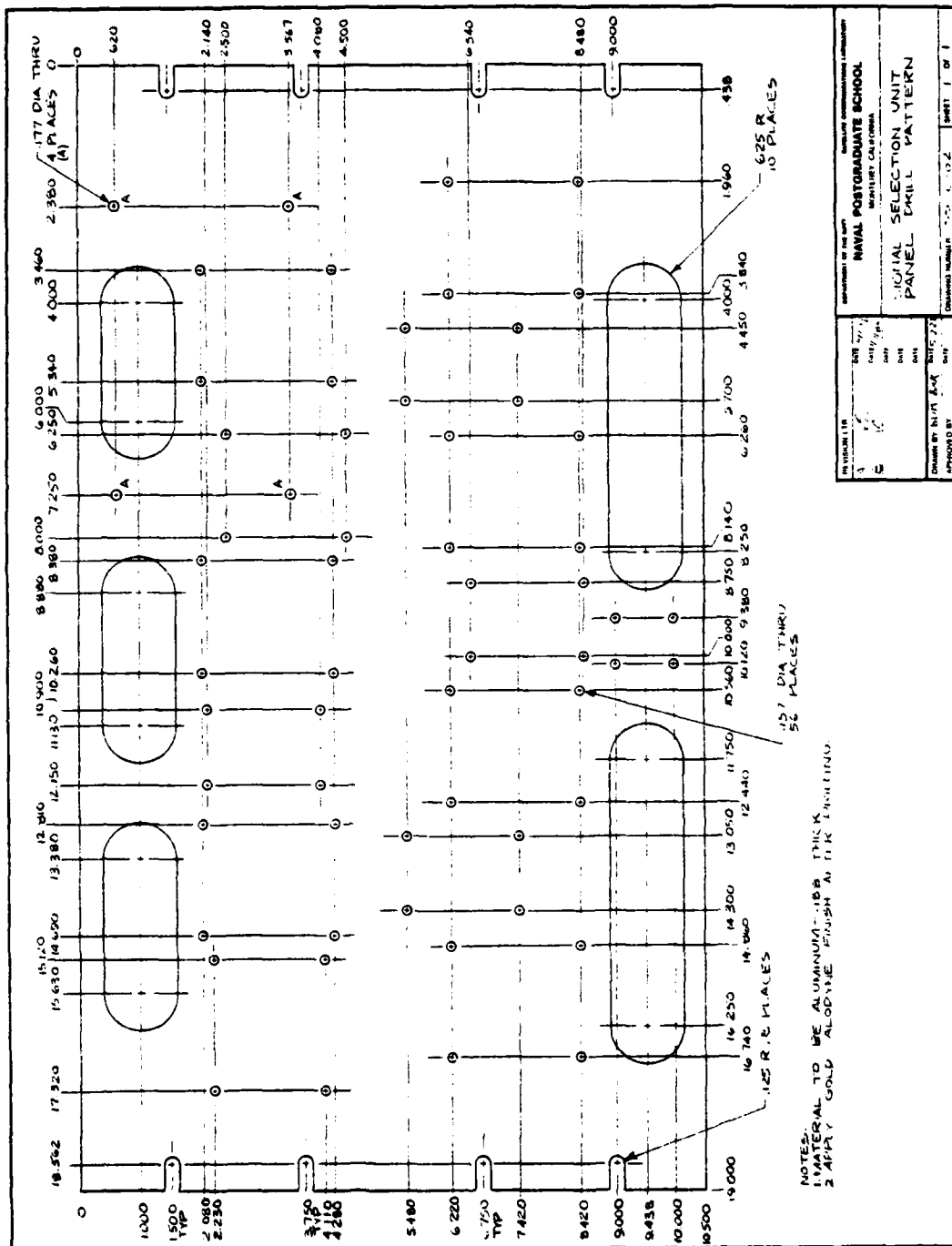


Figure E.5
Signal Selector Drill Pattern

APPENDIX F

SIGNAL SELECTOR (SS) DETAILED TEST PROCEDURES

1. Determine Path Continuity
 - a. Connect RF signal generator (sig gen) to J1.
Suggested RF sig gen is HP8660C RF Signal Generator or equivalent.
 - b. Set RF sig gen frequency to 75 MHz and output level to -55 dBm.
 - c. Select RC1 as input to SR1.
 - d. Connect spectrum analyzer to J11.
Suggested spectrum analyzer is HP8566A Spectrum Analyzer or equivalent.
 - e. Tune spectrum analyzer to view 75 MHz test signal.
 - f. If test signal appears on the spectrum analyzer, the path is good. Continue and check if the path can be broken by unselecting it.
 - g. Unselect RC1 as the input to SR1. There should be no signal selected for SR1.
 - h. The signal on the spectrum analyzer should disappear when RC1 is unselected.
 - i. If able to turn RC1 on and off, path is good.
 - j. Repeat above procedure with sig gen connected to jacks J2 - J7.
 - k. Repeat above procedure with spectrum analyzer connected to J12 - J17.
 - l. At this point a total of 43 paths should have been checked.
 - m. Connect sig gen to J1.
 - n. Connect spectrum analyzer to J8.
 - o. Signal will appear on spectrum analyzer if path is good. This path is not selectable.
 - p. Connect sig gen to J2.
 - q. Connect spectrum analyzer to J9.

- r. Signal will appear on spectrum analyzer if path is good. This path is not selectable.
- s. Connect sig gen to J3.
- t. Connect spectrum analyzer to J10.
- u. Signal will appear on spectrum analyzer if path is good. This path is not selectable.

2. Determine Frequency Response of Paths

- a. Connect sig gen to J1.
- b. Connect RF power meter to J11.
Suggested RF power meter is HP435A
Power Meter or equivalent.
- c. Set sig gen frequency to 75 MHz and output to -5 dBm.
- d. Note reading on the RF power meter. This is the reference value for this path.
- e. Sweep the sig gen from 60 - 90 MHz.
- f. During the sweep note the max and min deviations from the reference value. Also note the frequency where the maximum and minimum deviations occur.
- g. Repeat the above procedure (steps 1 - 6) with the sig gen connected to J2 - J7. Sweep input frequency as follows:

Input jack	Reference freq(MHz)	f(l) (MHz)	f(h) (MHz)	Expected loss(dB)
J2	75	60	60	11
J3	75	60	90	11
J4	125	110	140	8
J5	125	110	140	8
J6	125	110	140	12
J7	30	29.95	30.05	12

- h. Repeat the above procedure (steps 1 - 7) with the RF power meter connected to J12 - J17.
- i. At this point a total of 43 points should have been checked.
- j. Connect sig gen to J1.
- k. Connect RF power meter to J8.

- l. Repeat steps 4 - 6 using the parameters specified.
- m. Connect sig gen to J2.
- n. Connect RF power meter to J9.
- o. Repeat steps 4 - 6 using the parameters specified.
- p. Connect sig gen to J3.
- q. Connect RF power meter to J10.
- r. Repeat steps 4 - 6 using the parameters specified.

APPENDIX G

SPECTRUM RECEIVER (SR) CONNECTOR PINOUTS

A. RI-J9 CBL14 input

Pin	Byte	Bit	Function	Jack (on RI)	Pin	In/out
1	2	4	SR3 - BW1	J12	5	In
2	2	5	SR3 - BW2	J12	6	In
3	2	0	SR3 - 8 dB step	J12	1	In
4	2	1	SR3 - 16 dB step	J12	2	In
5	1	4	SR2 - BW1	J11	5	In
6	1	5	SR2 - BW2	J11	6	In
7	1	0	SR2 - 8 dB step	J11	1	In
8	1	1	SR2 - 16 dB step	J11	2	In
9	0	4	SR1 - BW1	J10	5	In
10	0	5	SR1 - BW2	J10	6	In
11	0	0	SR1 - 8 dB step	J10	1	In
12	0	1	SR1 - 16 dB step	J10	2	In
13	NA	NA	+5 v (NC)	(NC)	(NC)	In
14	NA	NA	+5 v (NC)	(NC)	(NC)	In
15	3	4	SR4 - BW1	J13	5	In
16	3	5	SR4 - BW2	J13	6	In
17	3	6	SR4 - 8 dB step	J13	1	In
18	3	1	SR4 - 16 dB step	J13	2	In
19	3	2	SR4 - 32 dB step	J13	3	In
20	3	3	SR4 - 32 dB step	J13	4	In
21	NA	NA	(NC)	(NC)	(NC)	
22	NA	NA	(NC)	(NC)	(NC)	
23	NA	NA	+5 v (NC)	(NC)	(NC)	In
24	NA	NA	+5 v (NC)	(NC)	(NC)	In
25	NA	NA	+5 v (NC)	(NC)	(NC)	In
26	2	6	SR3 - BW3	J12	7	In
27	2	7	SR3 - BW4	J12	8	In
28	2	2	SR3 - 32 dB step	J12	3	In
29	2	3	SR3 - 32 dB step	J12	4	In
30	1	6	SR2 - BW3	J11	7	In
31	1	7	SR2 - BW4	J11	8	In
32	1	8	SR2 - 32 dB step	J11	3	In
33	1	3	SR2 - 32 dB step	J11	4	In
34	0	6	SR1 - BW3	J10	7	In
35	0	7	SR1 - BW4	J10	8	In
36	0	2	SR1 - 32 dB step	J10	3	In
37	0	3	SR1 - 32 dB step	J10	4	In
38	NA	NA	+5 v	J12	15	In
39	NA	NA	+5 v	J11	15	In
40	3	6	SR4 - BW3	J13	7	In
41	3	7	SR4 - BW4	J13	8	In
42	NA	NA	GND	J11	9/10	
43	NA	NA	Enable 3 (NC)			In
44	NA	NA	Enable 2 (NC)			In
45	NA	NA	Enable 1 (NC)			In

46	NA	NA	+5 v	J12	15	In
47	NA	NA	+5 v	J10	15	In
48	NA	NA	Enable 0 (NC)			In
49	NA	NA	GND	J13	9/10	
50	NA	NA	GND	J10	9/10	
				J12	9/10	

B. SR(1,2,3,4)-J6 Control input from RI

<u>Pin</u>	<u>Function</u>	<u>In/out</u>
1	Step attenuator - 8 dB step	In
2	Step attenuator - 16 dB step	In
3	Step attenuator - 32 dB step	In
4	Step attenuator - 32 dB step	In
5	BW1 select	In
6	BW2 select	In
7	BW3 select	In
8	BW4 select	In
9	(NC)	
10	(NC)	
11	(NC)	
12	(NC)	
13	(NC)	
14	GND	
15	GND	

C. SR(1,2,3,4)-J7 Power connector

<u>Pin</u>	<u>Function</u>	<u>In/out</u>
A	+5 v	In
B	+5 v return	
C	-5 v	In
D	-5 v return	
E	+15 v	In
F	+15 v return	
G	-15 v	
H	-15 v return	
J	+28 v (NC)	In
K	+28 v return (NC)	
L	-20 v (NC)	In
M	-20 v return (NC)	
N	Not assigned	
P	Not assigned	

APPENDIX H

SPECTRUM RECEIVER (SR) PARTS LIST

SYMBOL	DESCRIPTION
1. PD1	4 way power, Merrimac PDM-40-110 divider
2. MX1, MX2	mixers, Merrimac DMM-4-250
3. AMPL1, AMPL2	QB-300 amplifier, QBIT
4. AMPL3	QB-784 amplifier, QBIT
5. FL1	29.6/0.8-0 bandpass filter, K & L Microwave
6. FL2	7473A bandpass filter, Damon
7. FL3	7474A bandpass filter, Damon
8. FL4	7475A bandpass filter, Damon
9. FL5	29.5/0.6 bandpass filter, K & L Microwave
10. FL6	29.66/X3.0 bandpass filter, K & L Microwave
11. AT1, AT2, AT3, AT5	0 - 20 dB variable attenuator, Merrimac ARM-1
12. AT4	8 - 16 - 32 - 32 step attenuator DAICO 100D05089-4-A-8, 16, 32, 32
13. AT6	6 dB fixed attenuator, ELCOM AT-51
14. J6	DA-15P connector, 15 pin
15. J7	MS3102A 22-19P power connector
16. S1	Lorch ES-391M SP4T RF Switch
17. A1	Lowpass filter assembly
a. R1	50 ohm, 1/4 W, 1%
b. R2, R3, R38, R4 2, R43	2K ohm, 1/4 W, 1%
c. R4, R5, R13, R14, R24, R40 R41	10K ohm, 1/4 W, 1%
d. R6, R8, R9	49.9K ohm, 1/4 W, 1%
e. R7	100K ohm potentiometer
f. R10, R21	100K ohm, 1/4 W, 1%
g. R11, R12	4.12K ohm, 1/4 W, 1%
h. R15, R26	50k ohm potentiometer
i. R16, R27	4.99K ohm, 1/4 W, 1%
j. R17, R18, R28, R29 R39	6.04K ohm, 1/4 W, 1%
k. R19, R30	10K potentiometer (may be 10K - 50K)
l. R20, R31	470K ohm, 1/4 W, 1%
m. R22, R23	499, 1/4 W, 1%
n. R32, R33, R34, R35, R36	3.01K ohm, 1/4 W, 1%
o. R37	1.50K ohm, 1/4 W, 1%
p. R44, R45	8.06K ohm, 1/4 W, 1%
q. C1, C8, C9	5 pF ceramic disc
r. C2	1300 pF, 5%
s. C3	27 pF, 5%
t. C4	160 pF, 5%
u. C5	2 pF
v. C6	50 pF ceramic disc
w. C7	100 pF ceramic disc
x. C10, C14	2.2 uF tantalum cap, polarized
y. C11, C12, C15	

	C16	0.1 uF tantalum cap, polarized 35 WVDC
z.	C13, C17	10 uF, 50 WVDC electrolytic cap, polarized
aa.	C18 - C31	0.1 uF DIP capacitors
bb.	FL7	1.5 MHz 3 dB TTE lowpass filter
cc.	FL8	310 kHz 3 dB TTE lowpass filter
dd.	U1, U6, U7	LM318 operational amplifier
ee.	U2, U3	DATEL FLT-U2 Universal Hybrid Active Filter
ff.	U4	CD4052BE Dual 4 to 1 analog switch
gg.	U5	7400 quad NAND gate
hh.	U8, U9	3553AM Burr Brown buffer amplifier
ii.	VR1	7912, -12v voltage regulator
jj.	VR2	7905, -5v voltage regulator
kk.	VR3	7812, +12v voltage regulator
ll.	VR4	7805, +5v voltage regulator
mm.	J8	SMA female chassis connector
nn.	J9	DA-15P D connector, 15 pin
oo.	J10	DC filter type feedthru w/ground lug
pp.	J4, J5	SMA female coconnector w/hex nut and mounting clip
qq.	Misc	8" x 4" x 1 1/2" enclosure MODPAK model # 8 x 4 - 1 1/2 - 00 - 00 1 right angle mounting bracket 4 6/32, 3/8" screws 2 4/40, 1/4" screws 4 4/40, 3/8" screws w/nuts and lock washers (inside star) Printed circuit board

APPENDIX I
COMPONENT SPECIFICATIONS

A. Double Balanced Mixer

1. Circuit symbol: MX1, MX2
2. Manufacturer: Merrimac Industries, Inc.
3. Model: DMM-4-250
4. Specifications:

Frequency Range	
R & L ports	5 - 500 MHz
X port	DC - 500 MHz
Conversion loss (max)	8.0 dB
Isolation (min)	
L to R (to 100 MHz)	45 dB
(to 500 MHz)	40 dB
L to X (to 100 MHz)	35 dB
(to 500 MHz)	15 dB
R to X (to 100 MHz)	20 dB
(to 500 MHz)	15 dB
1 dB compression point (min)	+8 dBm
Useful LO drive	+17 dBm
Noise figure	Conversion loss + 1 dB
Impedance	50 ohms
Max input power	+24.8 dBm
Temperature range	-59 to 100 C (operating)

B. Coaxial Switch

1. Circuit symbol: S1
2. Manufacturer: Lorch Electronics
3. Model: ES-391M
4. Specifications:

Configuration	SP4T
TTL compatible	active low
VSWR	1.5 : 1
Self terminating, unused port impedance	50 ohms
Insertion loss (max)	1 dB
Isolation (min)	70 dB
1 watt non-destruct frequency range	20 - 400 MHz
Switching time	10 microseconds
DC power required (max)	+5 v at 170 ma -5 v at 150 ma

C. Step Attenuator

1. Circuit symbol: AT4
2. Manufacturer: Daico Industries, Inc.
3. Model: 100D0589-4-A-8, 16, 32, 32
4. Specifications:

Attenuation steps	8, 16, 32, 32
Insertion loss	+4 dB / step
Switching speed	1 microsecond
Control	TTL compatible Active low, bit simple
VSWR (max)	1.35 : 1
Impedance	50 ohms
Frequency range	20 - 300 MHz
1 dB compression point	+13 dBm

D. Variable Attenuator

1. Circuit symbol: AT1, AT2, AT3, AT5
2. Manufacturer: Merrimac Industries
3. Model: ARM-1
4. Specifications:

Frequency Range	DC ~ 400 MHz
Insertion loss	2.0 dB
Trimming range	0 - 20 dB
Drive Control	Screw / lock

E. Power Divider

1. Circuit symbol: PD1
2. Manufacturer: Merrimac Industries
3. Model: PDM-40-110
4. Specification:

Frequency range	20 - 200 MHz
Theoretical loss	6 dB
Isolation	30 dB
Insertion loss	.7 dB
Impedance	50 ohms
VSWR	1.3 : 1
Connectors	SMA female
Power (max)	2 watts

F. 800 kHz Tubular Filter

1. Circuit symbol: FL1
2. Manufacturer: K & L Microwave, Inc.
3. Model: 6B114-29.6/X0.8-0
4. Specifications:

.25 dB bandwidth	800 kHz
Center frequency	29.6 MHz
Insertion loss	3.5 dB
Connectors	SMA female
60 dB bandwidth	10 MHz
	29.6 MHz +/- 5.0 MHz

G. 3.0 MHz Tubular Bandpass Filter

1. Circuit symbol: FL6
2. Manufacturer: K & L Microwave, Inc.
3. Model: 2B340-29.6/X3-0
4. Specifications:

.5 dB bandwidth	3.0 MHz
Center frequency	29.6 MHz
Insertion loss	0.7 dB
Connectors	SMA female
60 dB bandwidth	10 MHz
	29.6 MHz +/- 5.0 MHz

H. 4 kHz Crystal Bandpass Filter

1. Circuit symbol: FL2
2. Manufacturer: Damon Corporation
3. Model: 7475A
4. Specifications:

Passband Ripple	+/- .25 dB
Impedance	50 ohms
Connectors	SMA female
Insertion loss (max)	8.0 dB
VSWR (max)	1.5 : 1
Max non-destruct input power	+18 dBm
Nominal center frequency	29.9955 MHz
Lower .5 dB point (max)	29.9935 MHz
Upper .5 dB point (min)	29.9975 MHz
Lower 60 dB point (max)	29.9895 MHz
Upper 60 dB point (min)	30.0015 MHz
Spurious response (max) (within 3 MHz of center frequency)	-50 dB

I. 32 kHz Crystal Bandpass Filter

1. Circuit symbol: FL3
2. Manufacturer: Damon Corporation
3. Model: 7474A
4. Specifications:

Passband ripple:	+/- .25 dB
Impedance	50 ohms
Connectors	SMA female
Insertion loss (max)	8.0 dB
VSWR (max)	1.5 : 1
Maximum non-destruct input power	+18 dBm
Nominal Center frequency	29.966 MHz
Lower .5 dB point (max)	29.950 MHz
Upper .5 dB point (min)	29.982 MHz
Lower 60 dB point (max)	29.918 MHz
Upper 60 dB point (min)	30.014 MHz
Spurious response (max) (within 3 MHz of center frequency)	-50 dB

J. 115 kHz Crystal Bandpass Filter

1. Circuit symbol: FL4
2. Manufacturer: Damon Corporation
3. Model: 7473A
4. Specifications:

Passband ripple	+/- .25 dB
Impedance	50 ohms
Connectors	SMA female
Insertion loss (max)	3.0 dB
VSWR (max)	1.5 : 1
Maximum non-destruct input power	+18 dBm
Nominal center frequency	29.895 MHz
Lower .5 dB point (max)	29.840 MHz
Upper .5 dB point (min)	29.950 MHz
Lower 60 dB point (max)	29.7575 MHz
Upper 60 dB point (min)	30.0325 MHz
Spurious response (max) (within 3 Mhz of center frequency)	-50 dB

K. 600 kHz Hybrid Bandpass Filter

1. Circuit symbol: FL5
2. Manufacturer: K & L Microwave, Inc.
3. Model: 12B54-29.5/X0.6-0
4. Specifications:

Center frequency	29.5 MHz
Insertion loss	12.0 dB
Impedance	50 ohms
Passband ripple	+/- .25 dB
VSWR (max)	1.5 : 1
Lower .5 dB point (max)	29.2 MHz
Upper .5 dB point (min)	29.8 MHz
Lower 35 dB point (min)	28.8 MHz
Upper 35 dB point (min)	30.2 MHz
Connectors	SMA female

L. +22 dB Amplifier

1. Circuit symbol: AMPL1, AMPL2
2. Manufacturer: Q-Bit Corporation
3. Model: QB-300
4. Specifications:

Gain	+22 dB
1 dB compression point	+ 22dBm
Noise figure	3.5 dB
Frequency range	1 - 300 MHz
VSWR	1.5 : 1
Connectors	SMA female
DC power	15 - 24 v at 130 ma

M. + 80 dB Amplifier

1. Circuit symbol: AMPL3
2. Manufacturer: Q-Bit Corporation
3. Model: QB-784
4. Specifications:

Gain	+ 80 dB +/- 3 dB
1 dB compression point	+ 13 dBm
Noise figure	+ 3 dB
Frequency range	10 - 250 MHz
VSWR (max)	1.5 : 1
Connectors	SMA female
DC power	15 - 20 v at 200 ma

N. Lowpass Filter Assembly

1. Circuit symbol: A1
2. Manufacturer: Naval Postgraduate School
3. Model: drgl
4. Specifications:

Gain	29.7 dB
Input impedance	50 ohms
Output impedance	50 ohms
Maximum input without saturation	210 mvrms
Bandwidths	4 selectable
Control	TTL compatible, bit simple, active low
0.2 dB cutoff frequency	
BW1	7.2 kHz
BW2	58 kHz
BW3	186 kHz
BW4	800 kHz
3 dB cutoff frequency	
BW1	12 kHz
BW2	97 kHz
BW3	310 kHz
BW4	1.5 MHz
10 dB cutoff frequency	
BW1	18 kHz
BW2	146 kHz
BW3	465 kHz
BW4	2.2 MHz
DC power	+15 v at 200 ma -15 v at 180 ma

APPENDIX J

SPECTRUM RECEIVER (SR) BLUEPRINTS

This appendix contains the blueprints necessary to construct the Spectrum Receiver. The blueprints contained in the appendix are:

- | | | |
|-----|---------|--------|
| 1. | RI-C-00 | 1 of 2 |
| 2. | SR-C-00 | 1 of 2 |
| 3. | SR-C-00 | 2 of 2 |
| 4. | SR-C-00 | 1 of 3 |
| 5. | SR-C-01 | 2 of 3 |
| 6. | SR-C-01 | 3 of 3 |
| 7. | SR-C-02 | 1 of 3 |
| 8. | SR-C-02 | 2 of 3 |
| 9. | SR-C-02 | 3 of 3 |
| 10. | SR-C-03 | 1 of 2 |
| 11. | SR-C-03 | 2 of 2 |
| 12. | SR-C-10 | 1 of 2 |
| 13. | SR-C-10 | 2 of 2 |
| 14. | SR-C-11 | 1 of 1 |
| 15. | SR-C-12 | 1 of 1 |
| 16. | SR-C-13 | 1 of 1 |
| 17. | SR-C-14 | 1 of 2 |
| 18. | SR-C-14 | 2 of 2 |

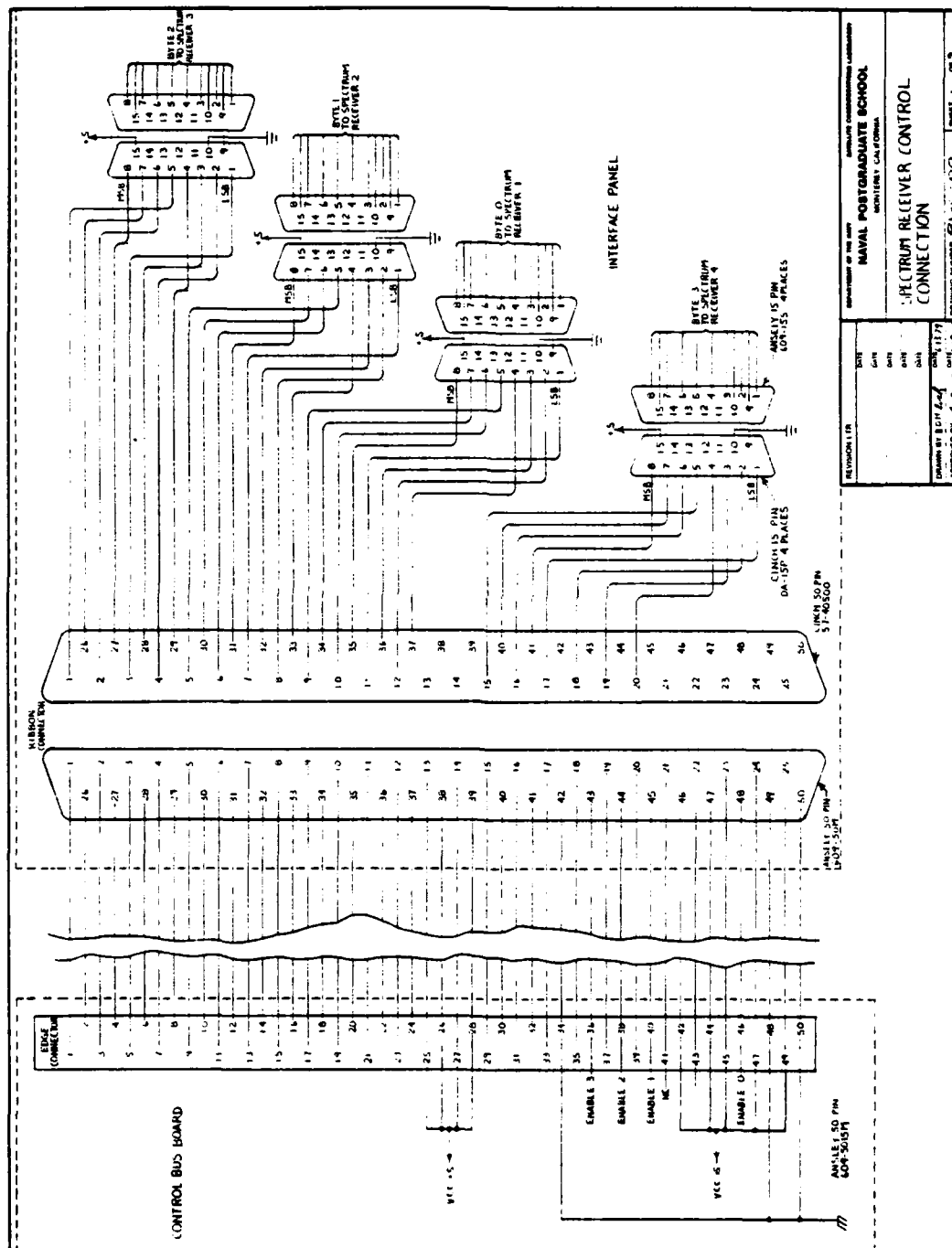
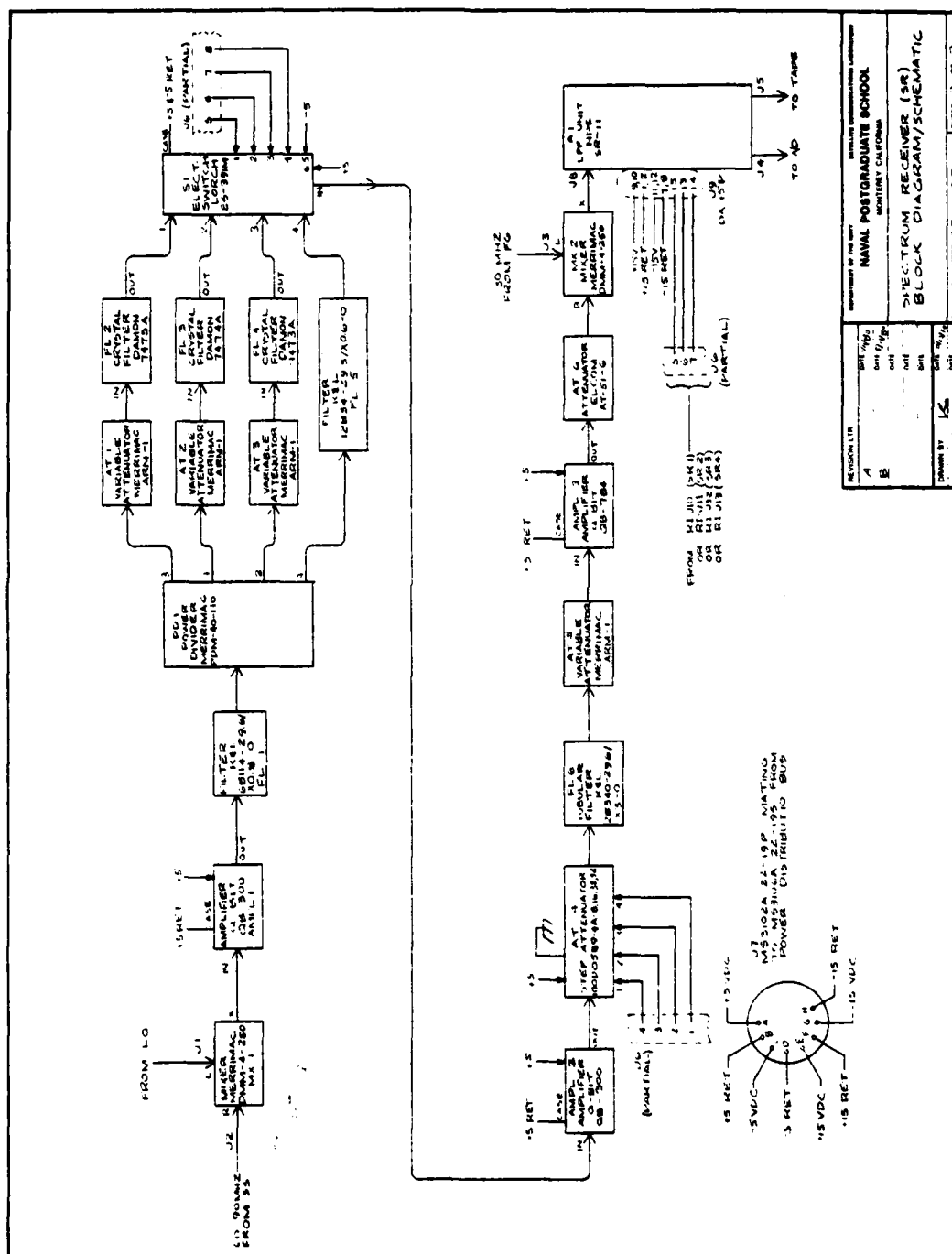


Figure J.1
Spectrum Receiver Control Interface



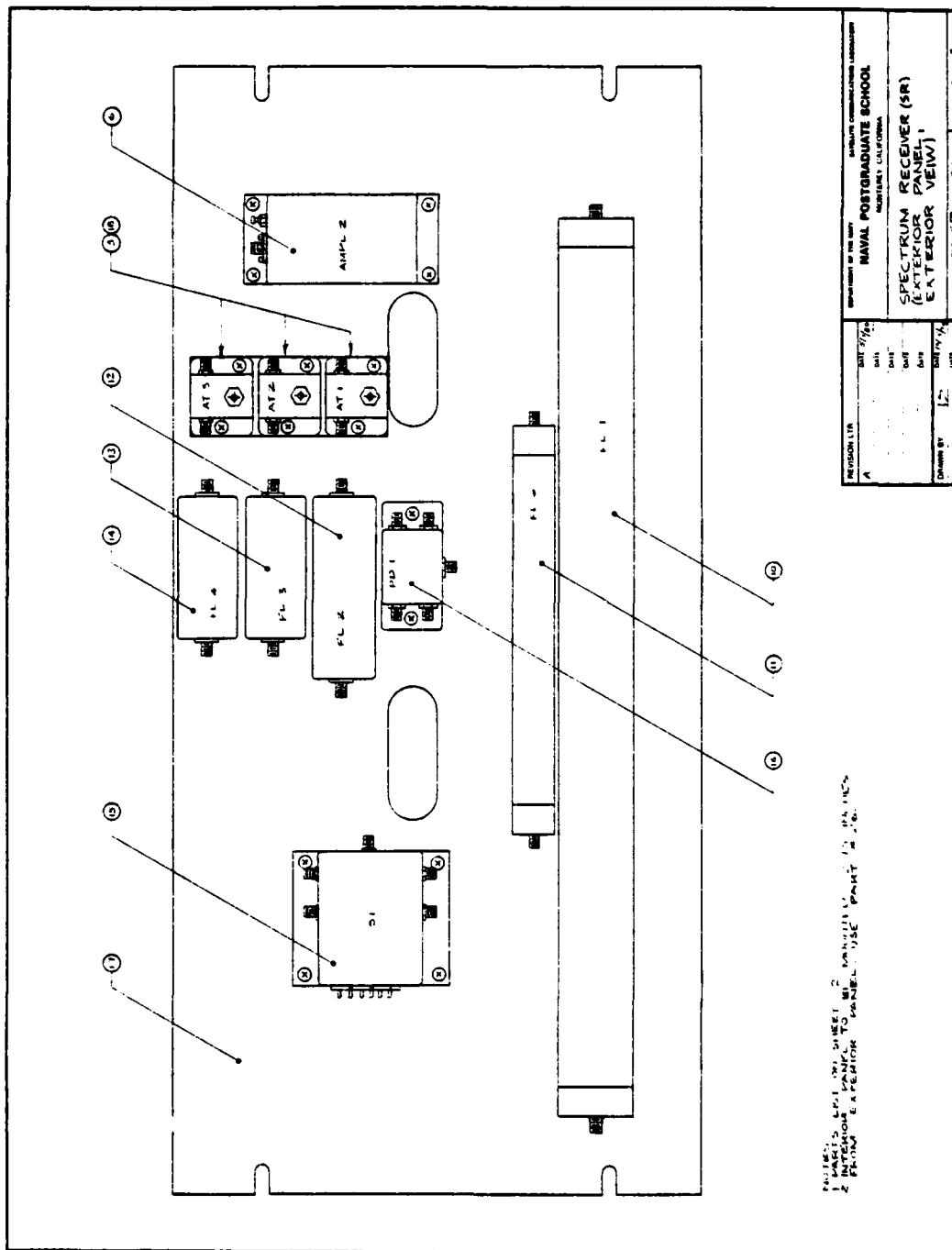
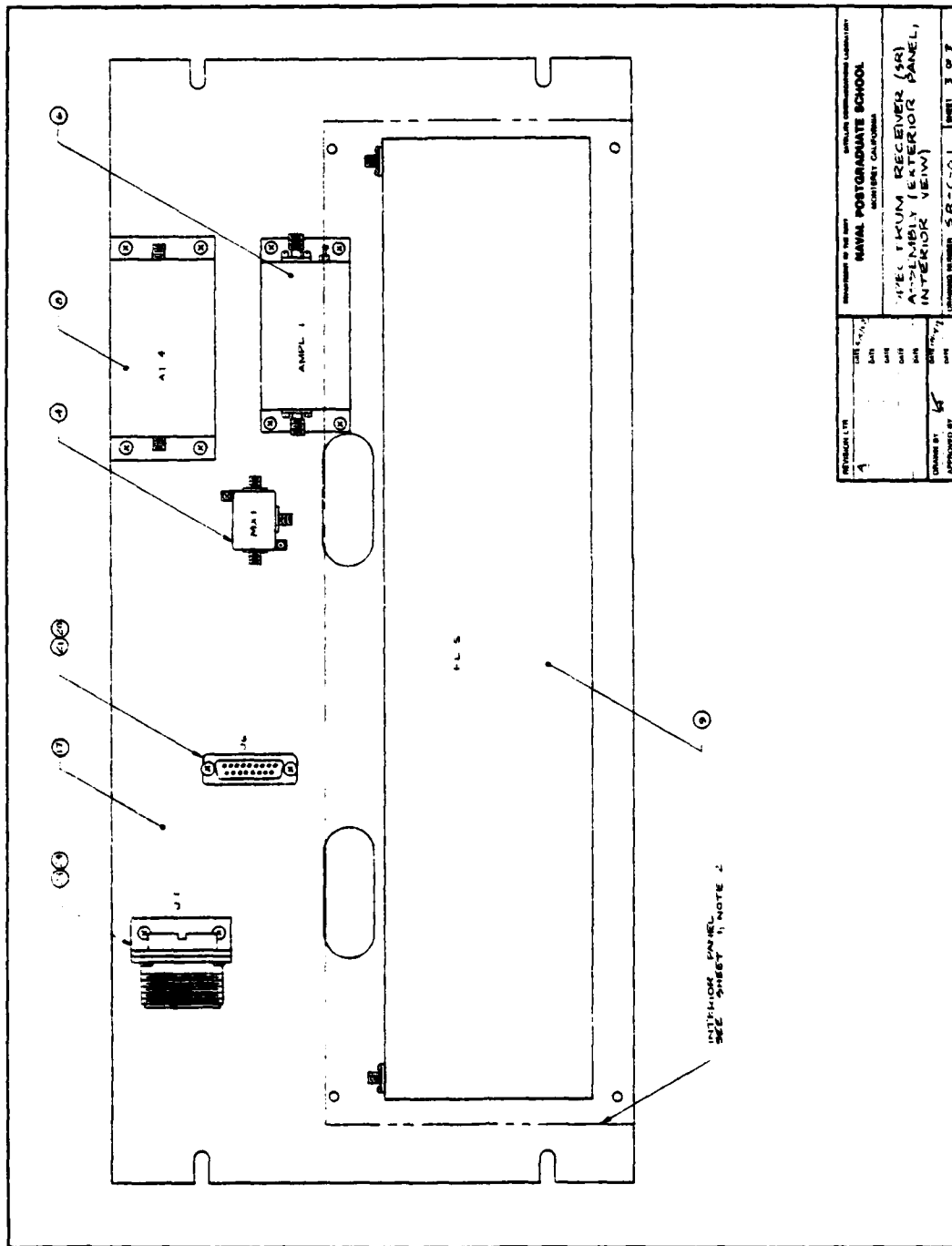


Figure J.4
Spectrum Receiver Assembly Exterior Panel



REVISIONS		REVISIONS	
NO.	DATE	NO.	DATE
1		2	
DRAWN BY: <i>[Signature]</i>		CHECKED BY: <i>[Signature]</i>	
APPROVED BY: <i>[Signature]</i>		APPROVED BY: <i>[Signature]</i>	
PROJECT: <i>[Blank]</i>		PROJECT: <i>[Blank]</i>	
SHEET: 3 OF 7		SHEET: 3 OF 7	

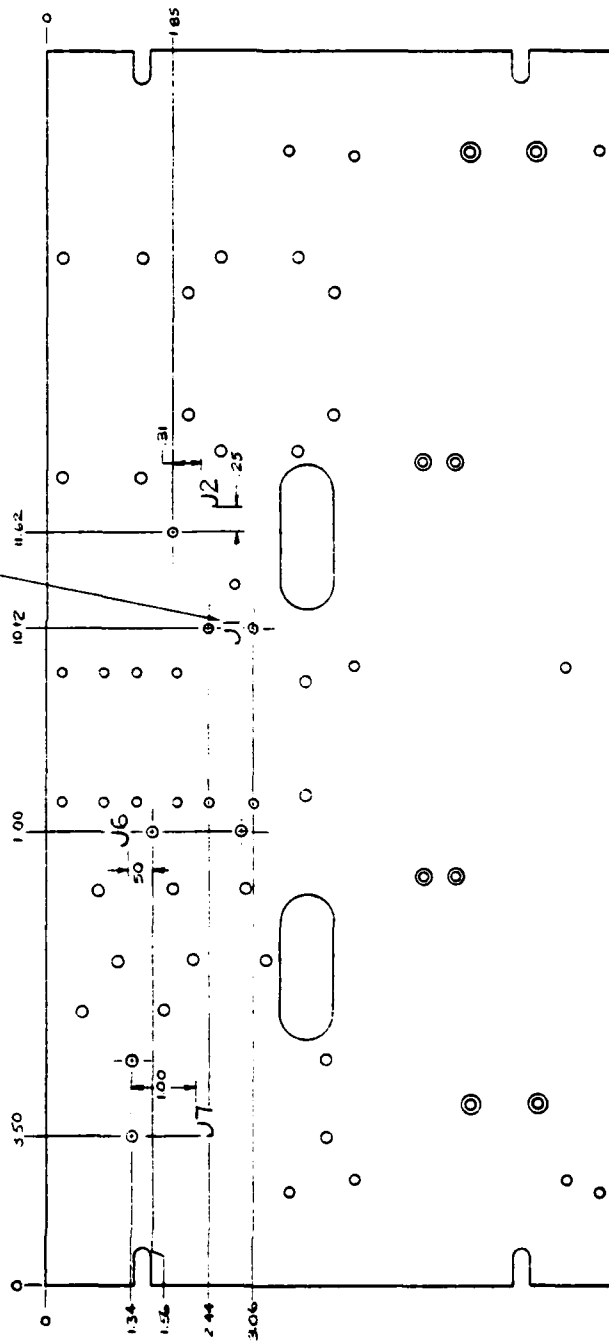
NAVAL POSTGRADUATE SCHOOL
MARIETTA, CALIFORNIA

SPECTRUM RECEIVER (SR)
ASSEMBLY (EXTERIOR PANEL,
INTERIOR VIEW)

SR-C-01

Figure J.6
Spectrum Receiver Exterior Panel

CENTERED
WITH HOLES



DEPARTMENT OF THE NAVY NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA		SPECTRUM RECEIVER PLATE		SHEET 2 OF 2
NO. IN CHARGE 176	SA10 SA11 SA12 SA13 SA14	SA15 SA16 SA17 SA18 SA19	SA20 SA21 SA22 SA23 SA24	DRAWING NUMBER 16-100-0-2
DESIGNED BY 18	CHECKED BY			APPROVED BY

Figure J.8
Spectrum Receiver Exterior Panel (2)

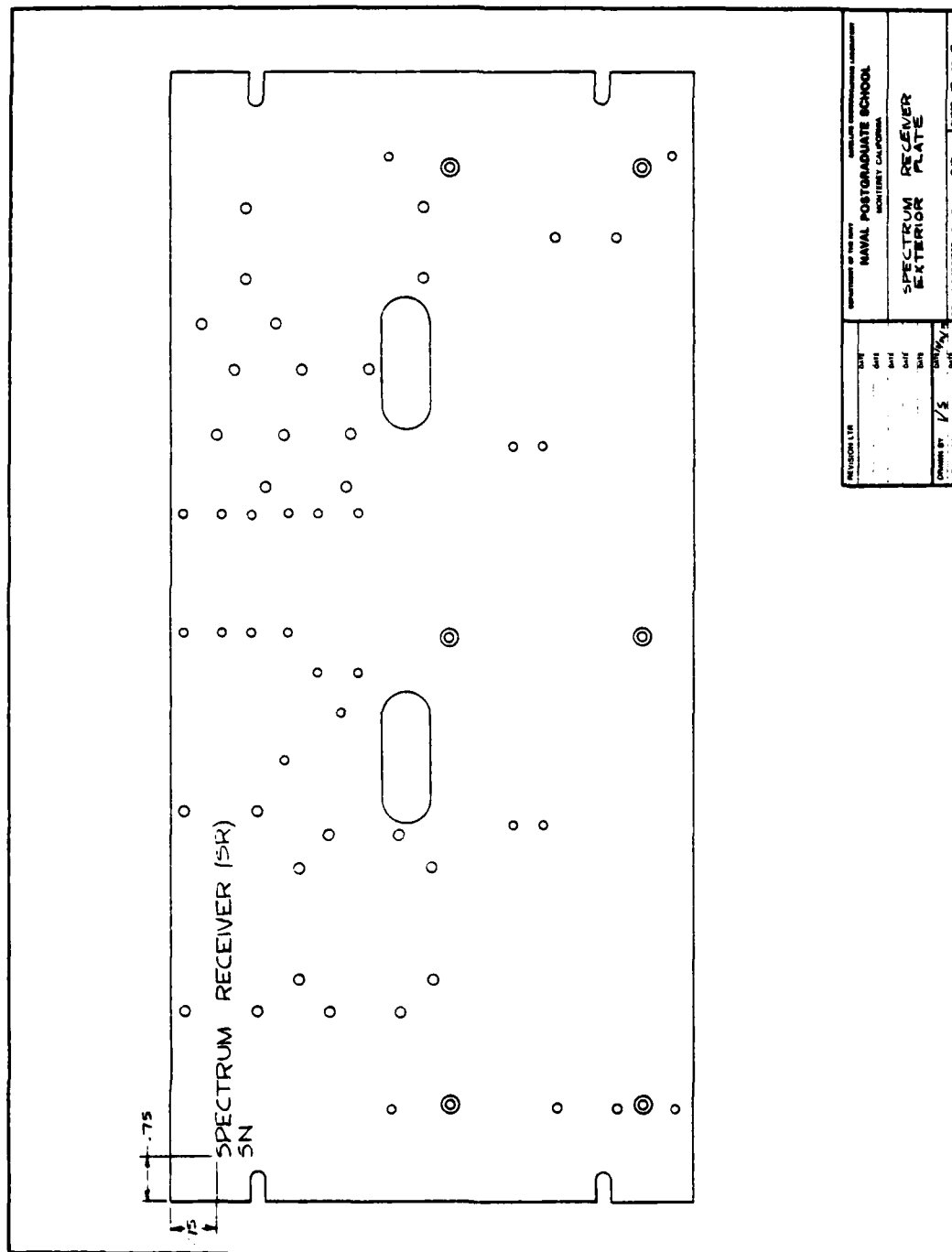


Figure J.9
Spectrum Receiver Exterior Panel (3)

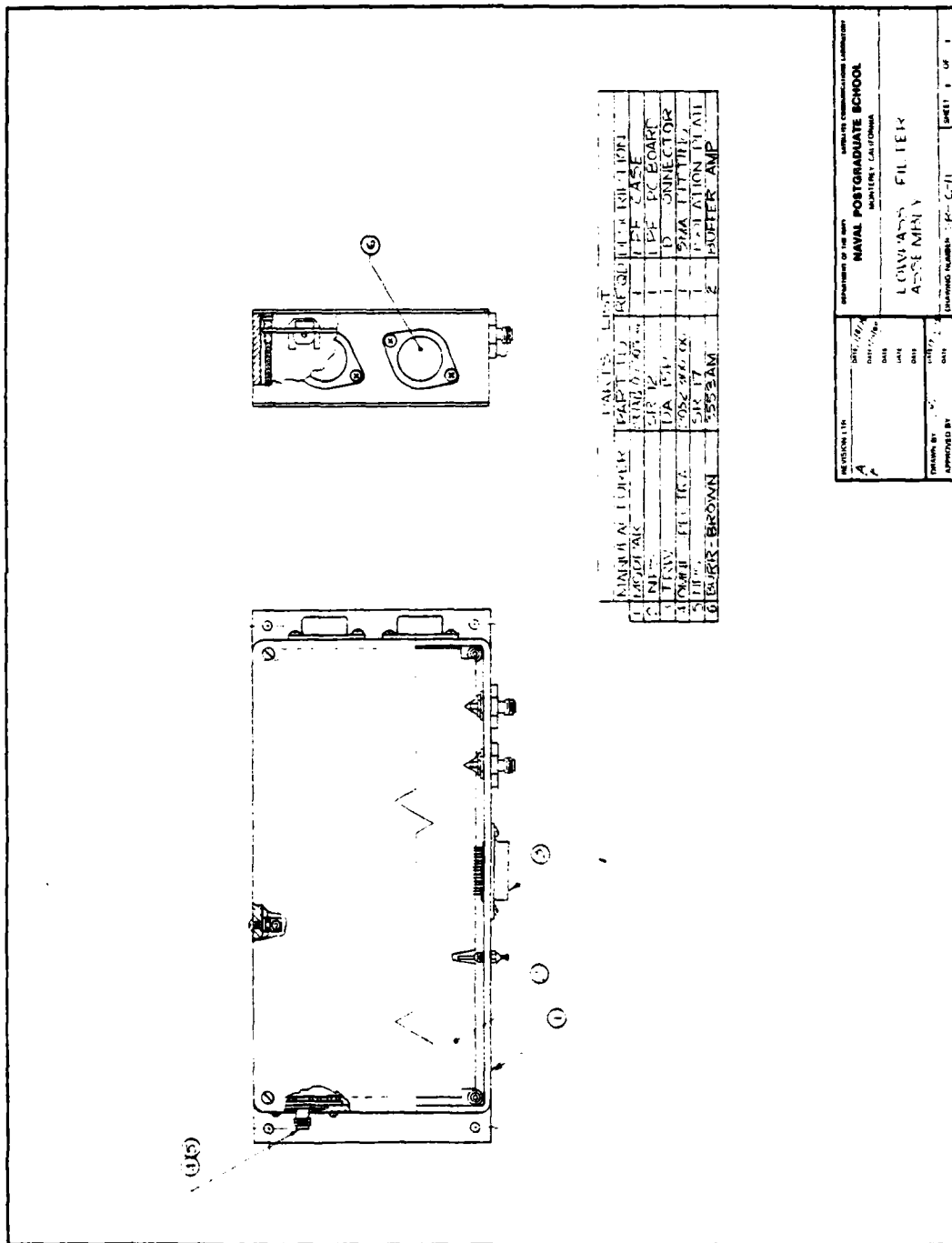
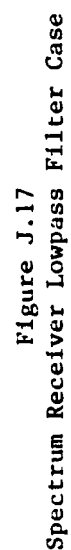


Figure J.14
Spectrum Receiver Lowpass Filter Assembly

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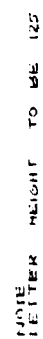


Figure J.18
Spectrum Receiver Lowpass Filter Case, Engraving Detail

APPENDIX K

ACTIVE FILTER DESIGN WITH THE FLT-U2 CHIP

Active filter design was greatly simplified by using DATEL's FLT-U2 Universal Active Hybrid Filter. The chip which was manufactured with thick film hybrid technology contains four op amps of which three have been committed to the state variable implementation of a second order transfer function. Figure K.1 illustrates the configuration of the basic chip and the placement of the external components. The fourth, uncommitted op amp may be used as a buffer amp or to increase the order of the transfer function to three. A third order Butterworth lowpass filter was implemented using only seven external resistors and one external capacitor. One of those resistors was variable in order to adjust the filter's Q and thereby provide a degree of freedom to change or align the cutoff frequency according to specifications.

The lowpass filters for the Lowpass Filter Unit (LPF) were designed using the inverting input and setting the overall gain to unity. By using the inverting input and all four op amps available on the chip, a non-inverted output was obtained. R2 is not required when using the inverting input. Unless otherwise specified circuit symbols in this appendix relate to the lowpass filter design in general and can be located in Figure K.1. R1 is 100K ohms and resistor R3 is calculated using:

$$R3 = (100K)/(3.80Q - 1)$$

for a Q of 1, R3 = 35.7K ohms. Using f(c) of 12 kHz

$$\begin{aligned} R4 = R5 &= [f(c) * 10^{**4}]/5000 \\ &= (12 * 10^{**7})/5000 = 2.4 K \text{ ohms} \end{aligned}$$

To implement the real axis pole the uncommitted op amp was used. In order to obtain overall unity gain

$$(R7/R6) = 1$$

choosing $R7 = 10K$ ohms, $R6 = 10K$ ohms, $C3$ was determined by the relationship

$$C3 = 1/[2(PI)f(c)R7] = 1326 \text{ pF}$$

where $f(c) = 12 * 10^{**} 3 \text{ Hz}$
 $R7 = 10K$ ohms.

TABLE IX
LOWPASS FILTER - EXTERNAL COMPONENTS

<u>BW</u>	<u>Symbol</u> <u>(Fig. K.1)</u>	<u>Symbol</u> <u>(Fig. J.13)</u>	<u>Value</u>
1	R1	R10	100K ohm
1	R2		open
1	R3	R15	35.7K ohm
1	R4	R11	4.12K ohm
1	R5	R12	4.12K ohm
1	R6	R13	10K ohm
1	R7	R14	10K ohm
1	R8	R16	4.99K ohm
1	C1	C2 + C3	1327 pF
2	R1	R21	100K ohm
2	R2		open
2	R3	R26	35.7K ohm
2	R4	R22	599 ohm
2	R5	R23	599 ohm
2	R6	R24	10K ohm
2	R7	R25	10K ohm
2	R8	R27	4.99K ohm
2	C1	C4 + C5	162 pF

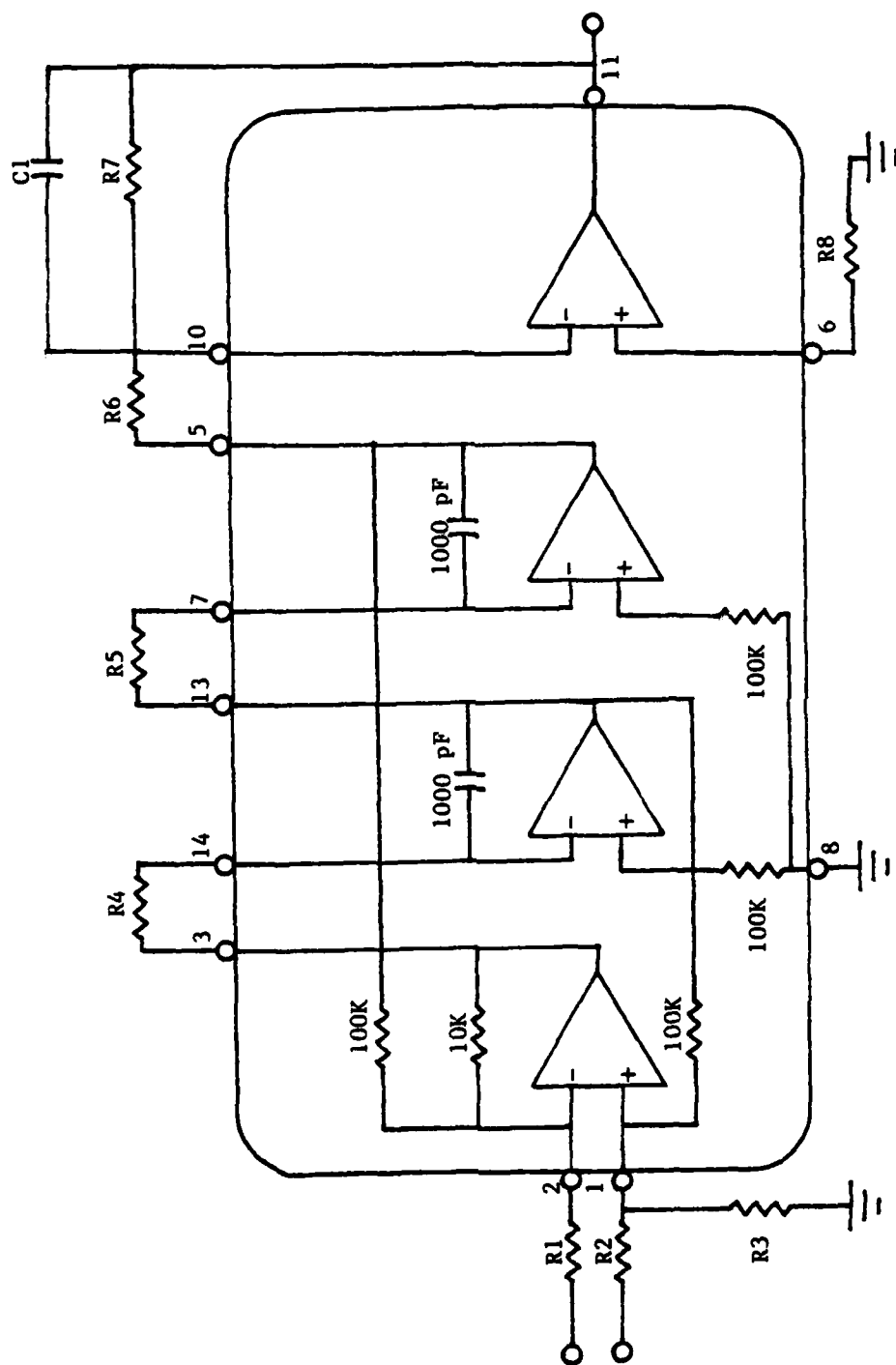


Figure K.1
FLT-U2 Component Identification

APPENDIX L

SPECTRUM RECEIVER (SR) DETAILED TEST PROCEDURES

I. Summary of Alignment/Test Procedures

- A. Align LPF
 - 1. Set Initial Zero Offset
 - 2. Align Lowpass Filter #1
 - 3. Align Lowpass Filter #2
- B. Align Spectrum Receivers (SR)
- C. Series of More Complicated Tests
 - 1. Measure Signal Levels Within SS-SR
 - 2. Test SR for Noise
 - 3. Determine Power In vs Power Out Characteristics
 - 4. Determine Range of AT5 (Master Gain Control)
 - 5. Determine Frequency Response (Method 1)
 - 6. Determine Frequency Response (Method 2)

II. Details of Alignment/Test Procedures

- A. Align LPF
 - 1. Set Initial Zero Offset
 - a. Short the input (J8).
 - b. Connect voltmeter to J4 (output to A/D).
Use a 50 ohm feedthru if necessary. Read DC volts.
Suggested voltmeter is HP3404C True RMS Voltmeter or equivalent.
 - c. Select BW4.
 - d. Adjust R7 so that voltmeter reads 0 volts.
 - e. Select BW3 - note reading. (There is no separate adjustment for this bandwidth.)
 - 2. Align Lowpass Filter #1 (0 - 12kHz, 3 dB)
 - a. Connect signal generator to input (J8).
 - b. Set sig gen to 12 kHz, output = .5 vrms (+7 dBm).
Suggested sig gen is HP3330B Automatic Synthesizer or equivalent.

- c. Connect voltmeter to J4 (output to A/D). Read AC volts (rms). Use 50 ohm feedthru if necessary.
 - d. Select BW1.
 - e. Adjust R15 so that voltmeter reads .354 vrms.
 - f. Switch to DC volts. Remove input line. Short input jack(J8). Adjust R19 for 0 volts DC. Remove short. Reconnect sig gen to input. Read AC volts (rms).
 - g. Set sig gen to 7.2 kHz (keeping sig gen output constant).
 - h. Voltmeter should read .489 vrms, if not readjust R15.
 - i. Set sig gen to 12 kHz (keeping sig gen output constant).
 - j. Voltmeter should read .354 vrms, if not readjust R15.
 - k. BW1 should be aligned.
3. Align Lowpass Filter #2 (0 - 97 kHz, 3 dB)
- a. Connect sig gen to input (J8).
 - b. Set sig gen to 97 kHz, output = .5 vrms (+7 dBm).
 - c. Connect voltmeter to J4 (output to A/D). Read AC volts (rms). Use 50 ohm feedthru if necessary.
 - d. Select BW2.
 - e. Adjust R26 so that voltmeter reads .354 vrms.
 - f. Switch to DC volts. Remove input line. Short input jack (J8). Adjust R30 for 0 volts DC.
 - g. Remove short. Reconnect sig gen to input. Read AC volts (rms).
 - h. Set sig gen to 58 kHz (keeping output constant).
 - i. Voltmeter should read .489 vrms, if not readjust R26.
 - j. Set sig gen to 97 kHz (keeping output constant).

k. Voltmeter should read .354 vrms, if not readjust R26.

1. BW2 should be aligned.

B. Align Spectrum Receiver (With LPF Assembly Connected)

1. Connect SR to appropriate output on SS.
2. Connect RF sig gen to SSJ1.
Suggested RF sig gen is HP8660C RF Signal Generator or equivalent.
3. Select RC1 to SR ().
4. Select SR(), BW4, FREQ = 256.0 MHz, 16 dB attenuation.
5. Set RF sig gen to 76 MHz, -55 dBm.
6. Connect voltmeter to J4, read AC volts (rms).
Use 50 ohm feedthru if necessary.
Suggested voltmeter is HP3404C True RMS Voltmeter or equivalent.
7. Adjust AT5 so that voltmeter reads 2.11 vrms.
8. Select BW1.
9. Adjust AT1 so that voltmeter reads 2.11 vrms.
10. Select BW2.
11. Adjust AT2 so that voltmeter reads 2.11 vrms.
12. Select BW3.
13. Adjust AT3 so that voltmeter reads 2.11 vrms.

At this point the SR should be completely aligned and ready for use in the Satellite Signal Analyzer (SSA).

C. A Series of More Complicated Tests

1. Test SR for Noise

- a. Connect SR to appropriate output on SS.
- b. Connect RF sig gen to SSJ1. FREQ = 76 MHz, output level = -95 dBm.
Suggested RF sig gen is HP8660C RF Signal Generator or equivalent.
- c. Select RC1 to SR ().
- d. Select SR (), BW4, FREQ 256.0 MHz, 16 dB attenuation.
- e. Connect spectrum analyzer to J4. (No 50 ohm feedthru necessary if spectrum analyzer input is 50 ohms.)
Suggested spectrum analyzer is HP model 141T system with HP8554B RF Section and HP-8552B IF Section or an equivalent system.
- f. Adjust spectrum analyzer as follows:
 - (1) Scan width/div = 20 kHz
 - (2) BW = 10 kHz
 - (3) Video filter = 100 Hz
- g. Locate SR output spectrum at approximately 500 kHz.
- h. Adjust sig gen power out to produce the following display on the spectrum analyzer.



- i. Connect sig gen to spectrum analyzer.
- j. Readjust spectrum analyzer to read the sig gen output power. (Sig gen output power = C.)
- k. Calculate receiver noise temperature:

$SNR = SNR(\text{true}) = SNR(\text{observed}) - 2.5 \text{ dB}$
(2.5 dB correction for video filter effects)

$N_o = kT(\text{rcvr}) = C / (SNR * B)$
(B = 12 kHz, for given spectrum analyzer setting)
(C in Watts, B in Hertz, $k = 1.38 * 10^{-23}$)
 $T(\text{rcvr}) = C / (SNR * B * k)$

$T(\text{rcvr})$ = noise temperature of the receiver
referenced to the Signal Selector (SS) input.

1. Calculate $T(\text{rcvr}/\text{ant})$.

$T(\text{rcvr}/\text{ant})$ = noise temperature of the receiver
referenced back through + 38 dB system gain to the
antenna terminals.

$$T(\text{rcvr}/\text{ant}) = T(\text{rcvr}) / (6.31 * 10^{**3})$$

38 dB - - -> $6.31 * 10^{**3}$

2. Determine Power In vs. Power Out Characteristics

- a. Connect SR() to appropriate output on SS.
- b. Connect RF signal generator to SSJ1. Freq = 76 MHz, initially set level to - 65 dBm.
Suggested RF signal generator is HP8660C RF Signal Generator or equivalent.
- c. Select RC1 to SR().
- d. Select SR() - BW4, FREQ = 256.0 MHz,
attenuation = 16 dB.
- e. Connect AC voltmeter to J4 (output to A/D).
Use a 50 ohm feedthru if necessary.
Suggested voltmeter is HP3404C True RMS Voltmeter
or equivalent.
- f. Vary power level of RF sig gen from -65dBm
to -40 dBm in increments of 1 dBm. Note
reading on AC voltmeter at each step.
- g. Convert voltage reading to power (into a 50 ohm load).
- h. Plot power in (abscissa) vs. power out (ordinate).
- i. On the same plot construct a line with slope = 1
passing thru the -55 dBm power-in point. Note the
point where the vertical distance between the two
lines is 1 dB. This is the 1 dB compression point.

3. Determine Range of AT5 (Master Gain Adjust)

- a. Connect SR() to appropriate output on SS.
- b. Connect RF signal generator to SSJ1. Freq = 76 MHz, output level = -55dBm. Suggested RF signal generator is HP8660C RF Signal Generator or equivalent.
- c. Select RC1 to SR(), FREQ = 256.0 MHz, attenuation = 16 dB.
- d. Connect AC voltmeter to J4 (use a 50 ohm feedthru if necessary) thru a T connector. Connect an oscilloscope to the other leg of the T connector. Suggested voltmeter is HP3404C True RMS Voltmeter or equivalent. Suggested oscilloscope is Tektronix 475 Oscilloscope or equivalent.
- e. Adjust AT5 for maximum attenuation. Note AC voltmeter reading.
- f. While observing the sinewave on the oscilloscope, adjust AT5 in order to reduce attenuation. Stop adjusting when sinewave starts clipping. Note the reading on the AC voltmeter.
- g. Continue to decrease attenuation to minimum attenuation. The sinewave should be clipped on the positive and negative swings. Note the peak amplitude on the scope.
- h. Reset AT5 for 2.11 vrms output (for -55 dBm input set up in step 2 above).

4. Determine Frequency Response (Method 1)

- a. Connect SR() to appropriate output on SS.
- b. Connect RF signal generator to SSJ1, Freq = 76 MHz, output level = -55 dBm (initially). Suggested RF signal generator is HP8660C RF Signal Generator or equivalent. The signal generator used must have a sweep mode and provide a DC output voltage proportional to the output frequency.
- c. Select RC1 to SR(), FREQ = 256.0 MHz, attenuation = 16 dB, BW4.
- d. Connect AC voltmeter to J4 (use a 50 ohm feedthru if necessary). Suggested voltmeter is HP3404C True RMS Voltmeter. For this test the voltmeter must

have an output which provides a DC voltage proportional to the input voltage.

- e. Interconnect RF signal generator and AC voltmeter with X-Y plotter as in Figure L.1. Suggested X-Y plotter is HP7044A X-Y Recorder.
- f. Set the RF signal generator output level so that the AC voltmeter reads 1.5 volts (rms).
- g. Vary the frequency of the RF signal generator from 75.4 MHz to 76.6 MHz. Note the frequency which produces the maximum reading on the AC voltmeter. Set the frequency to this value and readjust the RF sig gen output level so that the AC voltmeter reads 1.5 volts.
- h. Set the X-Y plotter so that the voltages from 0.40 to 1.5 will appear on the graph.
- i. With pen down on the X-Y plotter vary the frequency from 75.4 MHz to 76.6 MHz. This should produce the frequency response curve for BW4.
- j. Lift pen. Vary frequency, first above then below 76 MHz, until voltmeter reads 1.34 volts. Mark these points. These two points are the upper and lower 1 dB points.
- k. Vary frequency, first above then below 76 MHz until the voltmeter reads 1.06 volts. Mark these points. These two points are the upper and lower 3 dB down points.
- l. Vary frequency, first above then below 76 MHz, until voltmeter reads .47 volts. Mark these points. These points are the upper and lower 10 dB down points.
- m. With the same test setup and procedure, plot frequency response curves for bandwidths 1, 2, and 3, changing only the bandwidth desired and the frequency window to be swept. Change these parameters as follows:

BW	WIDTH	
	f(l)	f(h)
1	75.995	76.005
2	75.970	76.030
3	75.925	76.075

where: f(l) = lower limit
f(u) = upper limit

5. Determine Frequency Response (Method 2)

- a. Connect SR() to appropriate output on SS.
- b. Connect RF signal generator to SSJ1, frequency = 76 MHz, output level = -55 dBm (initially), BW4. Suggested RF signal generator is HP8660C RF Signal Generator or equivalent.
- c. Select RC1 to SR(), FREQ = 256.0 MHz, attenuation = 16 dB, BW4.
- d. Connect AC voltmeter to J4. Use a 50 ohm feedthru if necessary. Suggested voltmeter is HP3404C True RMS Voltmeter or equivalent.
- e. Set RF signal generator output level so that AC voltmeter reads 1.5 volts (rms).
- f. Vary the frequency of the RF signal generator from 75.4 MHz to 76.6 MHz. Note the frequency which produces the maximum reading on the AC voltmeter.

Set the RF sig gen frequency to this value and readjust the RF sig gen output level so that the AC voltmeter reads 1.5 volts.
- g. Choose 100 equally spaced frequencies between 75.4 MHz and 76.6 MHz to observe AC voltmeter readings.
- h. Manually tune the RF sig gen to each frequency listed in step g. Tabulate the corresponding readings on the AC voltmeter.
- i. Make a plot of frequency (X axis) vs. voltage (Y axis). The points where the curve passes thru the 1.34 volt level are the 1 dB down points; where it crosses the 1.06 volt level, the 3 dB down points; and where it crosses the .47 volt level, the 10 dB down points.
- j. Repeat the above steps for bandwidths 1, 2, and 3, changing only the bandwidth desired and the frequency sweep width. Change these parameters as follows:

WIDTH		
BW	f(l)	f(h)
1	75.995	76.005
2	75.970	76.030
3	75.925	76.075

where: f(l) = lower limit
f(u) = upper limit

6. Measure Signal Levels Within SS-SR

- a. Connect SR() to appropriate output on SS.
- b. Connect RF signal generator to SSJ1, frequency = 76 MHz, output level = -55 dBm.
Suggested RF signal generator is HP8660C RF Signal Generator or equivalent.
- c. Select RC1 to SR(), FREQ = 256.0 MHz, ATTENUATION = 16 dB, BW4.
- d. Ensure A7 is adjusted for 2.11 vrms output at J4.
This implies bandwidths 1, 2, and 3 are similarly adjusted.
- e. Disconnect components at the following junctions and read the signal level with spectrum analyzer.
Suggested spectrum analyzer is HP8566A Spectrum Analyzer.

JUNCTION	
FROM	TO
SS	SR()
AMPL1	FL1
FL1	PD1
S1	AMPL2
AMPL2	AT4
FL6	AT5
AT5	AMPL3
AT6	M2
M2	LPF Assembly
J4	50 ohm load

- f. These levels may be compared against theoretical levels or against a previous list if one has been constructed.
- g. Repeat the above steps for bandwidths 1, 2, and 3.
Change only the desired bandwidth.

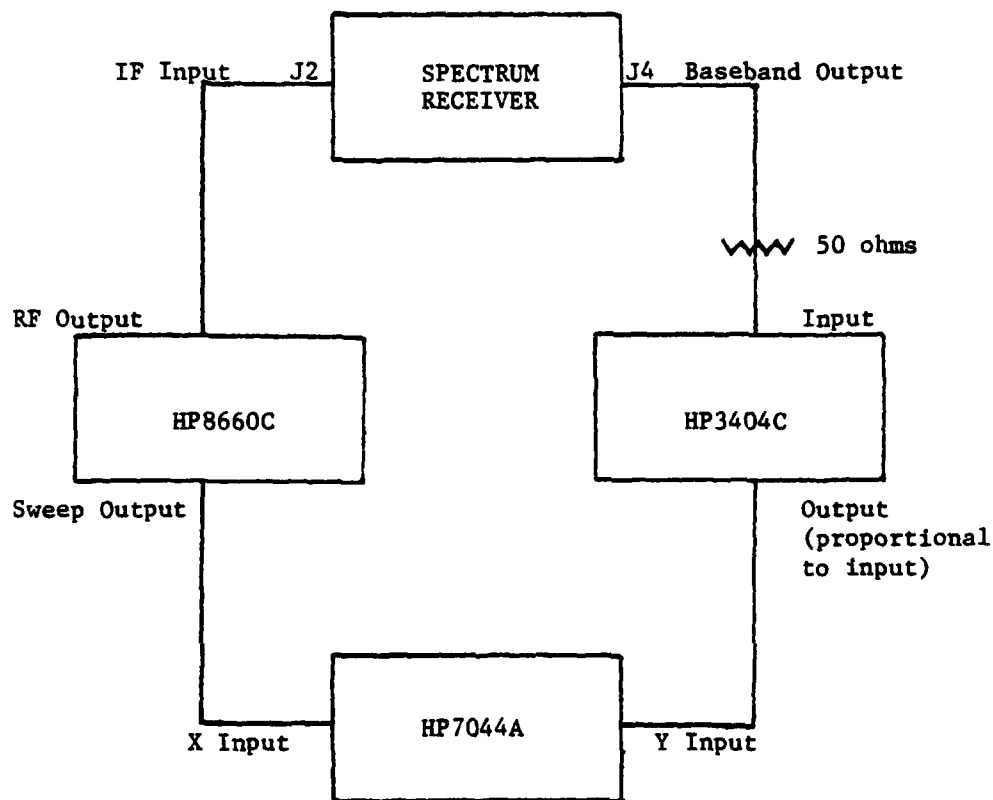


Figure L.1
Frequency Response Test Configuration

APPENDIX M

SR CALIBRATION - COMPUTER CONTROLLED (AUTOMATED)

The task of calibrating the SRs is accomplished when calibrating the entire Spectrum Receiver chain from the SS IF input to the spectrum display. To display an accurately plotted spectrum all component gains from the antenna to the display must be known. Each antenna chain will provide approximately +38 dB gain from the antenna to the Signal Selector input. All four receiver chains will be calibrated using one of the three antennas, then one of the receiver chains will be used to compute the calibration factors for the two remaining antennas. Two types of calibration runs must be made with the receivers. The (1) RF and (2) IF passband characteristics must be determined and a correction table generated. The Test Unit receiver test transmitter will provide the input; whereas, the array processor will actually calculate the amount of power received.

Calibrate RF Passband

This calibration must be done separately for the downlink and the uplink. The Test Unit will be used to generate a CW signal at a known frequency and power level. It will be inserted in the antenna chain at a point where the level of the test signal may be directly related through computations to the signal level received at the antenna. RF passband calibrations will be made with the following receiver chain parameters:

SR programmable attenuator - 16 dB
SR bandwidth - 30 kHz
A/D converter sampling rate - 153.846 kHz
block size - 1024 points
number of blocks averaged - 10

When doing the calibration for downlink signals the local oscillator frequency will be determined by

$$f(lo) = f(rf) - 180 + 29.866 \text{ (in MHz).}$$

where: $f(lo)$ = the local oscillator frequency
 $f(rf)$ = the RF input frequency.

Downlink signals will be in the range 240 - 270 MHz; therefore, the Test Unit receiver test transmitter must generate a set of discrete input test frequencies large enough to adequately characterize the RF passband. Great care must be taken to select the proper input test frequencies. Using the array processor as a monitoring device presents certain problems which must be considered. These problems and their solutions are discussed in a later section of this appendix. The computer algorithm for testing the RF passband consists of the following steps:

1. Set Test Unit receiver test signal to a constant power level.
2. Set Test Unit receiver test signal to 240 MHz.
3. Set up receiver for 30 kHz bandwidth, and 16 dB attenuation. (The corresponding array processor automatically sets the sampling rate specified earlier.)
4. Switch receiver test signal to antenna chain 1.
5. On the Signal Selector select antenna 1 downlink (RC1) as the input for SR1.
6. Set array processor block size to 1024 points and number of blocks averaged to 10.
7. Invoke array processor algorithm to compute power and display results.
8. Step test signal frequency from 240 to 270 MHz. Use RF input frequencies which when translated to baseband correspond to one of the discrete output frequencies of the array processor.

9. Using 260 MHz as the reference frequency calculate the power output deviation across the RF passband. Store these values in a look-up table to be used by the computer/array processor when this combination (antenna chain 1 and receiver chain 1) is selected.

Repeat the above algorithm for receiver chains 2, 3, and 4 changing receiver chain 1 to receiver chain 2, 3, and 4, respectively. Then repeat again as initially written changing antenna chain 1 to antenna chain 2, and 3.

If each downlink combination were tested, a total of 12 tests (4 receiver chains X 3 antenna chains) would be required. By assigning receiver chain 1 as the reference, half of the tests may be deleted. The other six correction tables must still be calculated, but they may be determined by the computer using data taken in the six tests defined above. This completely specifies the RF characteristics for each of the antenna chain - receiver chain combinations.

Calibrate IF Passband

This calibration is done in much the same way as the RF passband calibration with two major differences. The first difference is in the local oscillator frequency calculation. Since the object of the test is to characterize the four IF passbands of each receiver chain the local oscillator frequency must remain constant. This will allow the stepping of the RF input test signal to correspond to stepping a signal across the IF passband. Again the RF reference frequency will be 260 MHz. For each bandwidth a new local oscillator frequency will be calculated using $f(\text{rf}) = 260 \text{ MHz}$. It will then remain constant during testing of that particular bandwidth. For the IF passband characterization test only, the downlink local oscillator frequency will be calculated according to the following:

$$f(10) = 260 - 180 + f(i) \quad \text{MHz}$$

where $f(1) = 29.9955 \text{ MHz}$
 $f(2) = 29.966 \text{ MHz}$
 $f(3) = 29.895 \text{ MHz}$
 $f(4) = 29.5 \text{ MHz}$

and i corresponds to the bandwidth chosen.

The computer algorithm for testing the IF passband consists of the following steps.

1. Set the Test Unit receiver test signal to a constant power level.
2. On Signal Selector select antenna chain 1 downlink (RC1) as the input to receiver chain 1.
3. Input receiver test signal to antenna chain 1.
4. Set Test Unit receive signal to 260 MHz.
5. Set receiver chain 1 for bandwidth 1 (3 kHz bandwidth filters selected in SR1 and sampling rate 1 selected in analog-to-digital board 1) and 16 dB attenuation.
6. Set array processor block size to 1024 points and number of blocks averaged to 10.
7. Invoke array processor algorithm to compute power and display results.
8. Step test signal from 259.998 MHz to 260.002. Use RF input frequencies which when translated to baseband correspond to one of the discrete output frequencies of the array processor.
9. Using 260 MHz as the reference frequency calculate the power output deviation across the input frequency range. Store these values in the lookup table to be used by the computer/array processor when this combination (antenna chain 1, receive chain 1, bandwidth 1) is selected.

10. Repeat the above procedure for the remaining bandwidths 2, 3, and 4 of receiver chain 1, changing the bandwidth identification from 2, 3, and 4 respectively. The test signal frequency range will also vary according to the bandwidth under test. Use the following frequencies:

if in bandwidth 2 (30 kHz)	259.984 - 260.016	MHz
in bandwidth 3 (80 kHz)	259.945 - 260.055	MHz
in bandwidth 4 (600 kHz)	259.700 - 260.300	MHz

The sampling rate will change according to the bandwidth selected.

After calibrating the four bandwidths of receiver chain 1, the same algorithm should be applied to receiver chains 2, 3, and 4. It is necessary only to run calibration tests for all receiver chains and bandwidths with antenna chain 1 as an input. A total of forty eight downlink combinations (3 antenna chains X 4 receiver chains X 4 bandwidths) exist but actual calibration runs will only be done for the 16 combinations already described. The antenna chains are effectively calibrated once their RF characteristics are known.

The software will have to store 48 lookup tables for use in correcting the computed values of the FFT frequency components. In actual operation only one lookup table will be called up for each receiver chain. As soon as the antenna chain, receiver chain, and bandwidth have been selected the array processor can load the correction table into its memory to apply to its calculations.

General

It is desirable to determine the characteristics of the receiver chains using a CW test signal to allow observation at any one point in the RF spectrum or in the receiver IF. Since in normal operation the spectrum receiver output feeds the analog-to-digital converter and the array processor, it is natural to use such powerful devices to monitor and record the output. In doing so, the nature of the array processor

output must be considered. It performs a N point FFT on a set of N input voltage samples. Hence the array processor will compute the power spectrum for the input signal to the analog-to-digital converter. The output of the array processor is the power in any one of $N/2$ frequency bins; in other words, only the power contained in $N/2$ discrete frequencies will be computed. If no windowing is used and the input CW signal frequency does not fall on one of the discrete output frequencies, the picket fence effect will be grossly obvious and distorted results will be obtained.

The picket fence effect is a phenomenon introduced by the mathematics of the FFT. The sampling rate and the block size determine the size of the frequency bins the FFT produces. Given the proper conditions it is possible to do a FFT on a pure sinusoid and get ambiguous results, i.e. values for frequencies that were not present in the input signal. The effect is best illustrated by an example.

Given: input signal $f(t) = \cos [2(\pi)ft]$
block size $N = 8$ points
sampling frequency, $R_s = 80$ Hz
sampling window, $T_s = .1$ seconds

If the frequency, f , of the input signal is 10 Hz the resulting FFT power spectrum will be two spikes (delta functions) of value .25 watts. One spike appears at +10 Hz; the other, at -10 Hz. The total power is .50 watts. (See Figure M.1.)

Now change the f from 10 to 15 Hz. The resulting power spectrum will have a value for all frequency bins. Values (magnitudes only) for the FFT output points are:

0 Hz value = .016
+/- 10 Hz value = .180 (total)
+/- 20 Hz value = .246 (total)
+/- 30 Hz value = .044 (total)
R/2 = 40 Hz value = .017

(See figure M.2.) Although the total power is .5 watts, a display of the results would be very misleading. The input frequency was a sinusoid yet it did not produce the usual two spike power spectrum.

The spectrum display for the second input frequency is an example of the picket fence effect and how it can produce distorted results. The algorithm to be used in the calibration schemes will examine the power at the discrete baseband frequency corresponding to a known RF input frequency. The conclusion from this example is to avoid the picket fence effect when using the array processor to determine the RF and IF passband characteristics of the receiver chains.

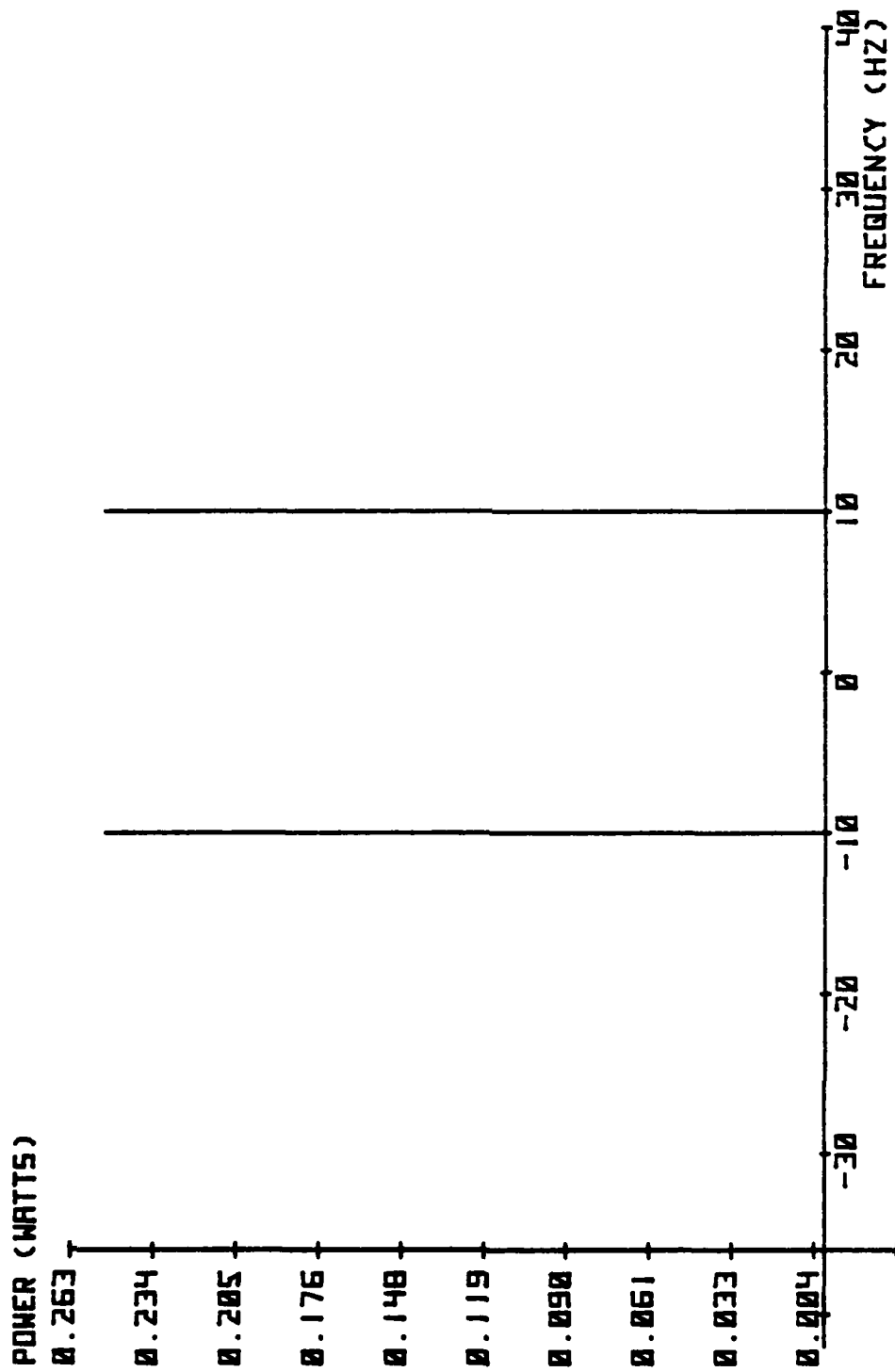


Figure M.1
8 Point Frequency Spectrum of a Sinusoid

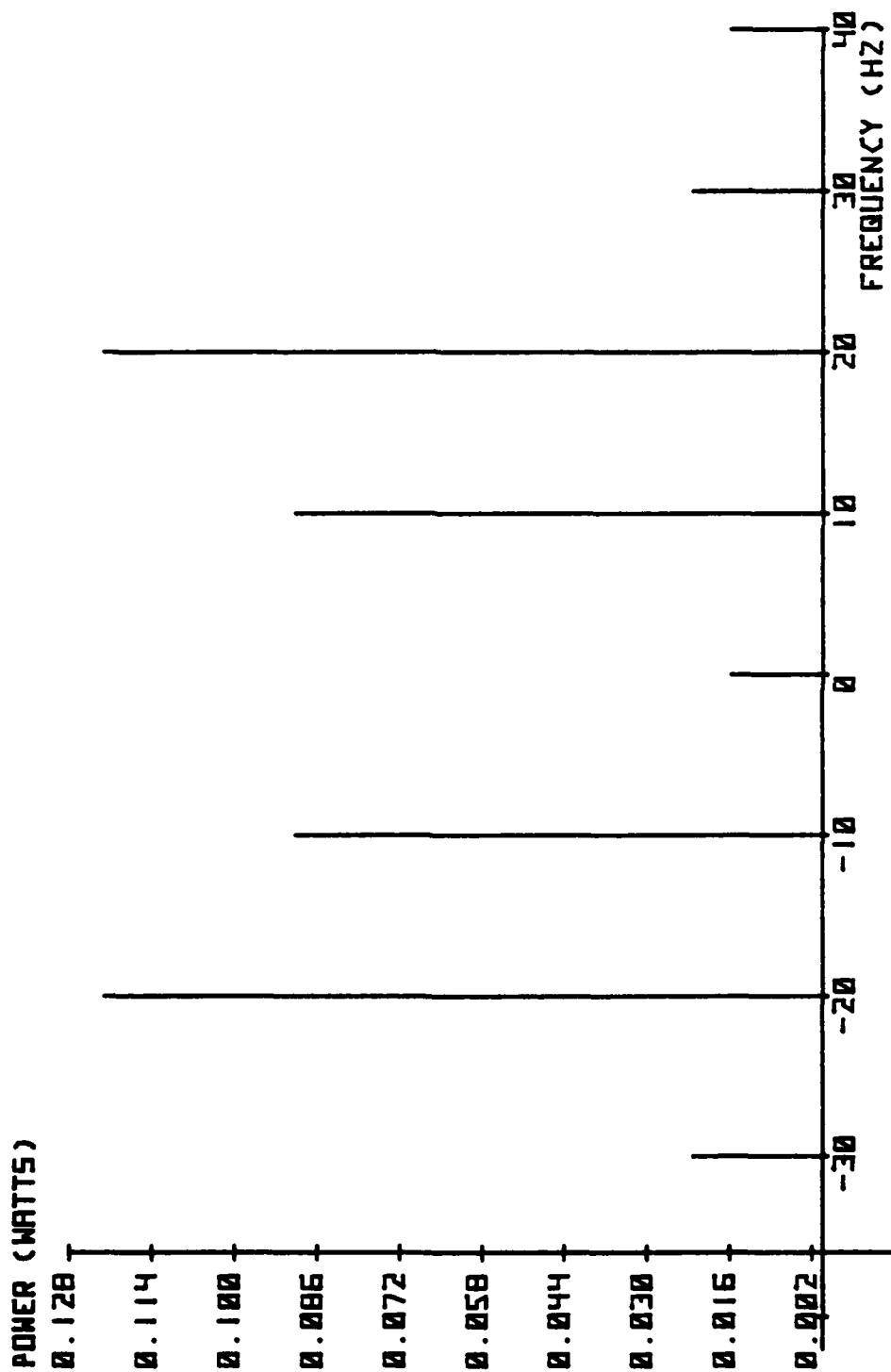


Figure M.2
8 Point Frequency Spectrum of a Sinusoid With Picket Fence Effect

APPENDIX N

MENU SOURCE FILE EXAMPLES

The menu source file examples contained in this appendix

are:

1. 'control0' (Labeled STARTMENU in figure R.1.)
2. 'task0'
3. 'status0'
4. 'help0'

1. 'control0' source file

```

control0                                menuid
                                     <<<<<<<<<< START MENU >>>>>>>>>>
co2                                     menutype
startmenu                             predecessor menu
`&dJLEFT SCREEN`&d@
Primary Guard:
    314 _____ 324 _____
]
r                                     button row beside text
11ALL^DNLINK                          button label
a                                     keyboard equivalent
prgrdlftad #                          control0
pb00100
11DNLINK^QUALTY
b
prgrdlftdq #                          control0
pb00104
11ALL^UPLINK
c
prgrdlftau #                          control0
pb00108
11UPLINK^QUALTY
d
prgrdlftuq #                          control0
pb00112
11SINGLE^CHAN
e
prgrdlftsc #                          control0
cmctr1013
pb00102
@
Secondary Guard:
    329 _____ 339 _____

-----
]
r
11ALL^DNLINK
f
secgdlftad #                          control0
pb00116
11DNLINK^QUALTY
g
secgdlftdq #                          control0
pb00120
11ALL^UPLINK
h
secgdlftau #                          control0
pb00124
11UPLINK^QUALTY
k

```

```

secgdlftuq # control10
pb00128
11SINGLE^CHAN
m
secgdlftsc # control10
tmctr1013
pb00118
@
~&dJRIGHT SCREEN~&d@
Primary Guard:
314 324
]
r
11ALL^DNLINK
n
prgrdrhtad # control10
pb00101
11DNLINK^QUALTY
q
prgrdrhtdq # control10
pb00105
11ALL^UPLINK
r
prgrdrhtau # control10
pb00109
11UPLINK^QUALTY
t
prgrdrhtuq # control10
pb00113
11SINGLE^CHAN
u
prgrdrhtsc # control10
tmctr1013
pb00103
@
Secondary Guard:
329 339
-----
]
r
11ALL^DNLINK
v
secgdrhtad # control10
pb00117
11DNLINK^QUALTY
w
secgdrhtdq # control10
pb00121
11ALL^UPLINK
x
secgdrhtau # control10
pb00125
11UPLINK^QUALTY

```

y	
secgdrhtuq #	control0
pb00129	
11SINGLE^CHAN	
z	
secgdrhtsc #	control0
tmctrl1013	
pb00119	
@	
OTHER=spectrum	
for other	
sats/sources	
]	
r	
11 OTHER^SATS	
7	
spectothst #	control0
dmctrl1001	
11FREQ^RCVR 1	
1	
spectfgrcl #	control0
dmctrl1026	
pb00020	
11FREQ^RCVR 2	
2	
spectfgrc2 #	control0
dmctrl1026	
pb00021	
11MODLTN^DISPLY	
3	
spectmodis #	control0
dmctrl1036	
pb00042	
11AN/^ WSC-3	
4	
spectwsc3 #	control0
dmctrl1050	
11KILL	
6	
tokillmenu #	control0
dmctrl1099	
@	

2. 'task0.m' source file

```
task0
task0 - SSA TASK
ca
startmenu
Select one.
]
0
@
```

```
POWER BALANCE
OPERATE AUDIO TAPE RECORDER
]
r
ll POWER^BALNCE
a
taskpurbal #
dmtask045
ca04500
ll AUDIO^TAPE
b
taskaudtap #
dmtask037
ca00101
@
```

```
SYSTEM TEST AND CALIBRATION
SATELLITE ASSIGNMENT
]
r
llTEST^& CAL
c
tasktescal #
ca00107
dmtask020
llSAT^ASSIGN
d
tasksatass #
dmtask001
ca00102
@
```

```
OPERATOR LOG IN
FAILED HARDWARE REPORTING
]
r
llOPER^LOG IN
e
taskoprlog #
dmtask059
ca00103
llFAILED^HARDWE
```

```
menuid
menutype
predecessor menu
```

```
button row beside text
button label
keyboard equivalent
task0
action:display menu
```

```
task0
```

```
task0
```

```
task0
```

```
task0
```

```
f
taskfdhdwe # task0
dmtask041
ca00104
@
]
r
llMORE^TASK
m
moretaskmm
dmtask100
llPREV^MENU
p
taskprmenu # task0
sm
@
```


3. 'status0.m' source file

status0		menuid
status0	CURRENT STATUS	
st		menutype
startmenu		predecessor menu
Select one.		
ALARMS	QUICK LOOK	
]		
r		button row beside text
llALARMS		button label
a		keyboard equivalent
curstaalrm #		status0
dmstat001		action:display menu
ll QUICK^LOOK		
b		
curstaqlk #		status0
dmstat002		
@		
DISPLAY		
]		
r		
llLEFT		
c		
curstaldis #		status0
dmstat003		
ll RIGHT		
d		
curstardis #		status0
dmstat004		
@		
FREQ RECEIVERS	AN/WSC-3	SPECTRUM
&		RECEIVERS
MODULATION DISPLAY		
]		
r		
llFREQ^ RCVRS		
e		
curstafrrc #		status0
dmstat005		
ll WSC-3		
f		
curstawsc3 #		status0
dmstat006		
llSPEC^ RCVRS		
g		
curstasrrc #		status0
dmstat007		
@		
TEST UNIT	AUDIO TAPE	
]		
r		

```

11TEST^UNIT
h
curstatstu # status0
dmstat008
11 AUDIO^TAPE
k
curstatape # status0
dmstat009
@
ACTIVE FAILED
SATELLITES HARDWARE
]
r
11ACTIVE^SATS
m
curstaasat # status0
dmstat010
11FAILED^HDWE
n
curstafhdw # status0
dmstat011
11PREV^MENU
p
curstaprmn # status0
sm
@

```

4. 'help0.m' source file

help0	menuid
help0 - SSA DOCUMENTATION	
he	menutype
startmenu	predecessor menu
HELP NOW - provides explanation	
for the last non-HELP menu.	
]	
r	button row beside text
llHELP^NOW	button label
n	keyboard equivalent
helpnow #	help0
dmhelp021	action:display menu
@	
SSA OPERATION	
]	
r	
llOPER	
r	
helpwopera #	help0
dmhelp031	
@	
HARDWARE	
]	
r	
ll ALPHA^LIST	
a	
hhwlistalf #	help0
dmhelp041	
llTYPE^LIST	
t	
hhwlisttyp #	help0
dmhelp051	
llLOCATE^LIST	
c	
hhwlistloc #	help0
dmhelp061	
@	
]	
r	
llPREV^MENU	
p	
hssadocumn #	help0
sm	
@	

APPENDIX O

'med' DIAGNOSTIC OUTPUT SAMPLES

The 'med' diagnostic output samples contained in this appendix are:

1. 'control0.mo'
2. 'task0.mo'
3. 'status0.mo'
4. 'help0.mo'

1. 'control0.mo', 'med' diagnostic output for 'control0.m'

control0

5 blocks, totalling 20 lines and 2039 image characters; 26 buttons
Menu type co with status fill-ins from block 2

Loc.	Size	Text lines	Buttons	Total lines
r	3	3	5	3
r	3	4	5	4
r	3	3	5	3
r	3	4	5	4
r	3	3	6	3

button label	key	loggingtxt	action/param	action/param	top	left
ALL^DNLINK	a	prgrdlftad	pb	100	0	1 36
DNLINK^QUALTY	b	prgrdlftdq	pb	104	0	1 45
ALL^UPLINK	c	prgrdlftau	pb	108	0	1 54
UPLINK^QUALTY	d	prgrdlftuq	pb	112	0	1 63
SINGLE^CHAN	e	prgrdlftsc	pb	102	tm 27	1 72
ALL^DNLINK	f	secgdlftad	pb	116	0	5 36
DNLINK^QUALTY	g	secgdlftdq	pb	120	0	5 45
ALL^UPLINK	h	secgdlftau	pb	124	0	5 54
UPLINK^QUALTY	k	secgdlftuq	pb	128	0	5 63
SINGLE^CHAN	m	secgdlftsc	pb	118	tm 27	5 72
ALL^DNLINK	n	prgrdrhtad	pb	101	0	9 36
DNLINK^QUALTY	q	prgrdrhtdq	pb	105	0	9 45
ALL^UPLINK	r	prgrdrhtau	pb	109	0	9 54
UPLINK^QUALTY	t	prgrdrhtuq	pb	113	0	9 63
SINGLE^CHAN	u	prgrdrhtsc	pb	103	tm 27	9 72
ALL^DNLINK	v	secgdrhtad	pb	117	0	13 36
DNLINK^QUALTY	w	secgdrhtdq	pb	121	0	13 45
ALL^UPLINK	x	secgdrhtau	pb	125	0	13 54
UPLINK^QUALTY	y	secgdrhtuq	pb	129	0	13 63
SINGLE^CHAN	z	secgdrhtsc	pb	119	tm 27	13 72
OTHER^SATS	7	spectothst		0	dm 14	17 27
FREQ^RCVR 1	1	spectfqrcl	pb	20	dm 13	17 36
FREQ^RCVR 2	2	spectfqrcl	pb	21	dm 13	17 45
MODLTN^DISPLY	3	spectmodis	pb	42	dm 12	17 54
AN/^ WSC-3	4	spectwsc3		0	dm 9	17 63
KILL	6	tokillmenu		0	dm 8	17 72

Menu id	No.
control0	4
startmenu	1
ctrl013	27
ctrl013	27
ctrl013	27
ctrl013	27
ctrl001	14
ctrl026	13
ctrl026	13
ctrl036	12
ctrl050	9

2. 'task0.mo', 'med' diagnostic output for 'task0.m'

task0

5 blocks, totalling 19 lines and 659 image characters; 8 buttons
Menu type ca

Loc.	Size	Text lines	Buttons	Total lines
0	3	1	0	1
r	3	3	2	3
r	3	3	2	3
r	3	3	2	3
r	3	0	2	3

button label	key	loggingtxt	action/param	action/param	top	left
POWER^BALNCE	a	taskpurbal	ca 4500	dm 97	4	63
AUDIO^TAPE	b	taskaudtap	ca 101	dm 78	4	72
TEST^& CAL	c	tasktescal	ca 107	dm 82	8	63
SAT^ASSIGN	d	tasksatass	ca 102	dm 137	8	72
OPER^LOG IN	e	taskoprlog	ca 103	dm 76	12	63
FAILED^HARDWE	f	taskfdhdwe	ca 104	dm 79	12	72
MORE^TASK	m	moretaskmm	0	dm 138	16	63
PREV^MENU	p	taskprmenu	0	sm 1	16	72

Menu id	No.
task0	6
startmenu	1
task045	97
task037	78
task020	82
task001	137
task059	76
task041	79
task100	138

3. 'status0.mo', 'med' diagnostic output for 'status0.m'

status0

5 blocks, totalling 20 lines and 1000 image characters; 12 buttons
Menu type st

Loc.	Size	Text	lines	Buttons	Total	lines
r	3		3	2		3
r	3		1	2		3
r	3		3	3		3
r	3		1	2		3
r	3		2	3		3

button label	key	loggingtxt	action/param	action/param	top	left
ALARMS	a	curstaalrm	0	dm	146	1 63
QUICK~LOOK	b	curstaqlk	0	dm	118	1 72
LEFT	c	curstaldis	0	dm	117	5 63
RIGHT	d	curstardis	0	dm	116	5 72
FREQ~ RCVRS	e	curstafrrc	0	dm	148	9 54
WSC-3	f	curstawsc3	0	dm	149	9 63
SPEC~ RCVRS	g	curstasrrc	0	dm	150	9 72
TEST~UNIT	h	curstatstu	0	dm	151	13 63
AUDIO~TAPE	k	curstatape	0	dm	152	13 72
ACTIVE~SATS	m	curstaasat	0	dm	153	17 54
FAILED~HDWE	n	curstafhdw	0	dm	154	17 63
PREV~MENU	p	curstaprmn	0	sm	1	17 72

Menu id	No.
status0	3
startmenu	1
stat001	146
stat002	118
stat003	117
stat004	116
stat005	148
stat006	149
stat007	150
stat008	151
stat009	152
stat010	153
stat011	154

4. 'help0.mo', 'med' diagnostic output for 'help0.m'

help0

4 blocks, totalling 17 lines and 466 image characters; 6 buttons
Menu type he

Loc.	Size	Text lines	Buttons	Total lines
r	3	2	1	3
r	3	1	1	3
r	3	1	3	3
r	3	0	1	3

button label	key	loggingtxt	action/param	action/param	top	left
HELP^NOW	n	helpnow	0	dm	115	2 72
OPER	r	helpwopera	0	dm	114	6 72
ALPHA^LIST	a	hhwlistalf	0	dm	113	10 54
TYPE^LIST	t	hhwlisttyp	0	dm	112	10 63
LOCATE^LIST	c	hhwlistloc	0	dm	105	10 72
PREV^MENU	p	hssadocumn	0	sm	1	14 72

Menu id	No.
help0	5
startmenu	1
help021	115
help031	114
help041	113
help051	112
help061	105

APPENDIX P

'menu' IMAGE FILE SAMPLES

The 'menu' image file samples contained in this appedix are:

1. 'control0.mu'
2. 'task0.mu'
3. 'status0.mu'
4. 'help0.mu'

[illegible]

2. 'menu' image file for 'task0.m'

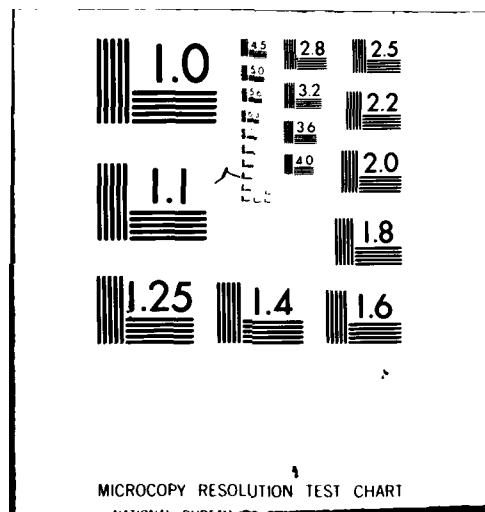
```
`&a00r12Ctask0 - SSA TASK~~&a02r12CSelect one.~~&a05r12CPower
BALANCE~~&a06r12COPERATE AUDIO TAPE RECORDER~~&a04r63C`1`&dJ
POWER`&d@`\\&dJBALNCE`&d@`\\&dJ a`&d@`3~~A`A `1`&dJ AUDIO`\\&dJ TAPE
`\\&dJ b`3~~&a09r12CSYSTEM TEST AND CALIBRATION~~&a10r12CSATELLITE
ASSIGNMENT~~&a08r63C`1`&dJ TEST `&d@`\\&dJ& CAL `&d@`\\&dJ
c`&d@`3~~A`A `1`&dJ SAT `\\&dJASSIGN`\\&dJ d`3~~&a13r12COPERATOR
LOG IN~~&a14r12CFAILED HARDWARE REPORTING~~&a12r63C`1`&dJ OPER
`&d@`\\&dJLOG IN`&d@`\\&dJ e`&d@`3~~A`A
`1`&dJFAILED`\\&dJHARDWE`\\&dJ f`3~~&a16r63C`1`&dJ MORE `&d@`\\&dJ
TASK `&d@`\\&dJ m`&d@`3~~A`A `1`&dJ PREV `\\&dJ MENU `\\&dJ p`3~~
```

3. 'menu' image file for 'status0.m'

```

~&a00r12Cstatus0          CURRENT          STATUS~~&a01r12CSelect
one.~~&a03r12CALARMS          QUICK          LOOK~~&a01r63C~1~&dJ
~&d@~\~&dJALARMS~&d@~\~&dJ      a~&d@~3~~A~A      ~1~&dJ QUICK~\~&dJ LOOK ~\~&dJ
b~3~~&a06r12CDISPLAY~~&a05r63C~1~&dJ      ~&d@~\~&dJ      LEFT ~&d@~\~&dJ
c~&d@~3~~A~A      ~1~&dJ      ~\~&dJ      RIGHT~\~&dJ      d~3~~&a09r12CFREQ RE-
CEIVERS          AN/WSC-3          SPECTRUM~~&a10r12C          &
RECEIVERS~~&a11r12CMODULATION DISPLAY~~&a09r54C~1~&dJ      FREQ ~&d@~\~&dJ
RCVRS~&d@~\~&dJ      e~&d @~3~~A~A      ~1~&dJ      ~&d@~\~&dJ WSC-3~&d@~\~&dJ
f~&d@~3~~A~A      ~1~&dJ SPEC ~\~&dJ RCVRS~\~&dJ      g~3~~&a14r12CTEST UNIT
AUDIO          TAPE~~&a13r63C~1~&dJ      TEST ~&d@~\~&dJ      UNIT ~&d@~\~&dJ
h~&d@~3~~A~A      ~1~&dJ AUDIO~\~&dJ TAPE ~\~&dJ      k~3~~&a17r12CACTIVE
FAILED~~&a18r12CSATELLITES
HARDWARE~~&a17r54C~1~&dJACTIVE~&d@~\~&dJ SATS ~&d@~\~&dJ      m~&d@~3~~A~A
~1~&dJFAILED~&d@~\~&dJ HDWE ~&d@~\~&dJ      n~&d@~3~~A~A      ~1~&dJ PREV
~\~&dJ MENU ~\~&dJ      p~3~~

```

4. 'menu' image file for 'help0.m'

`&a00r12Chelp0 - SSA DOCUMENTATION~~&a02r12CHELP NOW - provides
explanation~~&a03r12C for the last non-HELP menu.~~&a02r72C`1`&dJ HELP
\\&dJ NOW \\&dJ n`3~~&a07r12CSSA OPERATION~~&a06r72C`1`&dJ
\\&dJ OPER \\&dJ r`3~~&a11r12CHARDWARE~~&a10r54C`1`&dJ
ALPHA`&d@\\&dJ LIST `&d@\\&dJ a`&d@`3~~A`A `1`&dJ TYPE `&d@\\&dJ
LIST `&d@\\&dJ t`&d@`3~~A`A `1`&dJLOCATE\\&dJ LIST \\&dJ
c`3~~&a14r72C`1`&dJ PREV \\&dJ MENU \\&dJ p`3~~

APPENDIX Q

'mdir' LISTING

This appendix contains a sample 'mdir' listing.

startmenu	1
none	2
status0	3
control0	4
help0	5
task0	6
ctrl088	7
ctrl099	8
ctrl050	9
task005	10
task120	11
ctrl036	12
00	13
ctrl001	14
ctrl011	15
ctrl091	16
ctrl049	17
ctrl048	18
ctrl082	19
ctrl019	20
ctrl003	21
ctrl004	22
ctrl005	23
ctrl006	24
ctrl007	25
00	26
ctrl013	27
ctrl014	28
ctrl015	29
ctrl016	30
.	
.	
.	
ctrl083	72
ctrl079	73
ctrl078	74
ctrl094	75
task059	76
task052	77

.
.
.
task017 123
task080 140
task089 141
task003 142
task006 143
task007 144
task004 145
00 146
00 147

APPENDIX R

MENU DISPLAY SAMPLES

The menu display samples contained in this appendix are:

1. 'startmenu' ('control0')
2. 'ctrl001'
3. 'ctrl002'
4. 'ctrl003'
5. 'ctrl010'
6. 'ctrl011'
7. 'task0'
8. 'status0'
9. 'help0'

LEFT SCREEN		START MENU			
Primary Guard:	ALL DNLINK a	DNLINK QUALITY b	ALL UPLINK c	UPLINK QUALITY d	SINGLE CHAN e
Secondary Guard:	ALL DNLINK f	DNLINK QUALITY g	ALL UPLINK h	UPLINK QUALITY i	SINGLE CHAN m
RIGHT SCREEN		ALL DNLINK n	DNLINK QUALITY o	ALL UPLINK p	SINGLE CHAN u
Primary Guard:	ALL DNLINK v	DNLINK QUALITY w	ALL UPLINK x	UPLINK QUALITY y	SINGLE CHAN z
Secondary Guard:	OTHER=spectrum for other sats/sources	FREQ RCUR 1 1	FREQ RCUR 2 2	MODLN DISPLY 3	KILL 8
				AN/ WSC-3 4	

Figure E.1
'startmenu' ('control0') Menu Display

ctrl001 - AVAILABLE SATELLITES AND SOURCES

SELECT the SATELLITE or SOURCE SAME SAT/SOURCE
you wish to MONITOR. & CHAN/FREQ

1. ----- 2. -----
3. ----- 4. -----
5. ----- 6. -----

OTHER SOURCES

ANT 1
a

ANT 2
b

ANT 3
c

TAPE
PLAY
t

PREV
MENU
p

LEFT
SCREEN
d

RIGHT
SCREEN
e

1
1

2
2

3
3

4
4

5
5

6
6

Figure R.2
'ctrl001' Menu Display

ctr 1002 - SCREEN SELECT

LEFT SCREEN

ALL
ONLINE
a

ONLINE
QUALITY
b

ALL
UPLINK
c

UPLINK
QUALITY
d

SINGLE
CHAN
e

RIGHT SCREEN

ALL
ONLINE
f

ONLINE
QUALITY
h

ALL
UPLINK
i

UPLINK
QUALITY
m

SINGLE
CHAN
n

PREV
MENU
p

Figure R.3
'ctr1002' Menu Display

ctrl1003 - FLTSATCOM CHANNEL SELECT - ----- SCREEN

Select a CHANNEL or FREQ SELECT.
FREQ SELECT allows choice of a specific frequency.

AF = AIR FORCE
WB = WIDE BAND

NAVY 1	NAVY 2	NAVY 3	NAVY 4	NAVY 5
NAVY 6	NAVY 7	NAVY 8	NAVY 9	NAVY 10
ALL AF	SINGLE AF	WB 23	FREQ SELECT	FREQ MENU

Figure R.4
'ctrl1003' Menu Display

ctr1010 - DISPLAY - ---- SCREEN

DOWNLINK/UPLINK/INS

DISPLAY BANDWIDTH (kHz)

percent of display bandwidth - may repeat

FREQ
OFFSET

-50%
a

-10%
b

NO
OFFSET
c

+10%
e

+50%
f

DOWNLINK RECEIVE MODE:

SATCOM (-85dBm, max)

RFI LOW (-55dBm, max)

RFI HIGH (-25dBm, max)

MODIFY = RESOLUTION/AVERAGING/WATERFALL

DOWN LINK d	UP LINK u	IXS MODE x
30 2	80 2	600 4
repeat	AUTO CENTER y	LAST OFFSET v
NORMAL SATCOM n	RFI LOW l	RFI HIGH h
	MODIFY m	FREQ MENU f

Figure R.5
'ctr1010' Menu Display

ctrl011 - MODIFY - ----- SCREEN

NORMAL/WATERFALL

NORMAL n	UTPFL u
NORMAL a	HIGH f
NORMAL b	MAX c
	FREQ MENU e

RESOLUTION

LOW l	MEDIUM m
----------	-------------

AVERAGING

MIN s

Some combinations of DISPLAY BANDWIDTH, RESOLUTION, and AVERAGING have long update times, up to 30 seconds.

Figure R.6
'ctrl011' Menu Display

task0 - SSH TASK

Select one.

POWER BALANCE
OPERATE AUDIO TAPE RECORDER
SYSTEM TEST AND CALIBRATION
SATELLITE ASSIGNMENT

OPERATOR LOG IN
FAILED HARDWARE REPORTING

POWER BALANCE a	AUDIO TAPE b
TEST LOG IN c	GMT ASSIGN d
OPER LOG IN e	FAILED HARDWE f
OPER TASK g	PREV MENU h

Figure R.7
'task0' Menu Display

status0 Select one.	CURRENT STATUS	
ALARMS	QUICK LOOK	ALARMS QUICK LOOK
DISPLAY		LEFT RIGHT
FREQ RECEIVERS & MODULATION DISPLAY	AN WSC-3 SPECTRUM RECEIVERS	FREQ RECEIVERS WSC-3 SPECTRUM RECEIVERS
TEST UNIT	AUDIO TAPE	TEST UNIT AUDIO TAPE
ACTIVE SATELLITES	FAILED HARDWARE	ACTIVE SATS FAILED HARDWARE

Figure R.8
'status0' Menu Display

help0 - SSA DOCUMENTATION

HELP NOW - provides explanation
for the last non-HELP menu.

SSA OPERATION

HARDWARE

HELP
NOW

HELP

TYPE
LIST

REF
MENU

TYPE
LIST

ALPHA
LIST

Figure R.9
'help0' Menu Display

APPENDIX S

```

*****
#
#                               G P M E N U
#
# *****
#
# This program converts the menu image file used to produce the
# display on the HP 2649A graphics terminal into a series
# of commands which will essentially create the same display
# on the CONRAC large screen video monitors.
#
# menu(2040) = image file
# text(130)  = text buffer used to accumulate the menu text
#             characters for output to the Lexidata graphics
#             processor.
# ccnt      = text character count
# in        = menu( ) index
# char      = intermediate variable used for comparing menu(in)
#             with the various image characters.
# (HP)      = indication that a variable is defined relative
#             to the HP-2649A co-ordinate system
# (LEX)     = indication that a variable is defined relative
#             to the LEXIDATA Graphics Processor co-ordinate
#             system
# icol      = HP2649A column of next char to be stored (HP)
# irow      = HP2649A row of next char to be stored (HP)
# tabcol    = fixed column pointer (HP)
# iul       = underline flag (=1 then underline, else do not)
# ienh      = enhancement flag
#             (=0, then normal; =4, then reverse video)
# irowul    = start of underline vector (y co-ordinate) (HP)
# icolul    = start of underline vector (x co-ordinate) (HP)
# icolule   = end of underline vector (x co-ordinate) (HP)
# icoltx    = start of text buffer (x co-ordinate) (HP)
# irowtx    = start of text buffer (y co-ordinate) (HP)
# itx       = x coord of start of text buffer (LEX)
# itx       = y coord of start of text buffer (LEX)
# ixul      = x coord of underline start pixel (LEX)
# iyul      = y coord of underline start pixel (LEX)
# ixule     = x coord of underline end pixel (LEX)
# iyule     = y coord of end underline pixel (LEX)
# iwidth    = LEXIDATA character width (LEX)
# ihigh     = LEXIDATA character height (LEX)
# ix0       = x coord of initial start pixel (LEX)
# iy0       = y coord of initial start pixel (LEX)
# iunit     = graphics processor/display screen number
#             1 = right screen, 2 = left screen
# xspace    = vertical spacing between characters
# yspace    = horizontal spacing between characters

```

```

# uloff      = offset distance between bottom of character
#             and underline.

# Pointer notes: 'ccnt' points to the next text buffer
#                 position to be loaded. Therefore
#                 when dumping text buffer, decrement
#                 ccnt.
#                 'in' points to current image character
#                 being tested.
#                 'icol' points to the column where the next
#                 text character will be printed, or the
#                 next operation will occur.
#                 'irow' points to the current row where text
#                 is to be printed or an operation will
#                 occur.

# Initialize
#
logical*1 menu(2040), text(130)
integer ccnt, char, ch, txtfcn, xspace, yspace, uloff
common txtfcn, ccnt, text

icol=0; irow=0; ccnt=1; iul=0; ienhn=0

iwidth = 7; ihigh = 9

ix0 = -85; iy0 = 115

xspace = 2; yspace = 5

call gtmenu(menu)
#
# Check each character in the image file
# (Max image file = 2040 bytes)
#
for (in=1; in<=2040; in=in+1) {

ch = menu(in); char = ch + 256 * 32

if (char == '_') {

# Status fillin detected.
# ccnt points to next char to be loaded into text buffer.
# icol points to position of next character position.
# Must decrement both by three to return to valid text
# position. The current character being examined and
# the last two loaded into the text buffer are numbers
# specifying the byte location of the status fillins.

      icol = icol - 3; ccnt = ccnt - 3

# As long as the text characters are underlines, '_', read

```

```

# them into the text buffer. When a nonunderline is
# detected branch out of the loop and identify it.

while (menu(in) == '^') {
    ch = menu(in); char = ch + 256 * 32
    text(ccnt) = char
    ccnt = ccnt + 1; in = in + 1; icol = icol + 1
}
ch = menu(in); char = ch + 256 * 32
}

# The character must be one of the following.

# Is the character a '^' ?
# If yes, dump the text buffer
# before continuing.

if (char == '^') {
    ienhn=0
    if (ccnt != 1) {
        ixtx = ix0 + (icoltx * (iwidth + xspace))
        iytx = iy0 + (irowtx * (ihigh + yspace))
        call putext (iunit, ccnt, txtfcn, ienhn, ixtx, iytx)
        ccnt = 1
    }
}

# Is the character a '^', end of image ?
else if (char == '^')
    call exit

# Is the character a '^', tab ?
else if (char == '^') {

# Dump the text buffer if ccnt != 1.
    if (ccnt != 1) {
        ixtx = ix0 + (icoltx * (iwidth + xspace))
        iytx = iy0 + (irowtx * (ihigh + yspace))
        ccnt = ccnt - 1
        call putext(iunit, ccnt, txtfcn, ienhn, ixtx, iytx)
        ccnt = 1
    }

# Program stores only one tab position per line.
# If current position is < tab position, go to the
# tab position. If current position is >= tab
# position, go to the beginning of the next line.
    if (icol >= itab){
        irow = irow + 1
        icol = 0
    }
    else icol = itab
}

```

```

# Is character a ^^^ ? If so, identify the
# entire escape sequence.
# Dump text buffer if ccnt != 1.
else if (char == '^') {
    if (ccnt != 1){
        ixtx = ix0 + (icoltx * (iwidth + xspace))
        iytx = iy0 + (irowtx * (ihigh + yspace))
        ccnt = ccnt - 1
        call putext(iunit, ccnt, txtfcn, ienh, ixtx, iytx)
        ccnt = 1
    }

# Identify second character in the escape sequence.
    in = in + 1
    ch = menu(in); char = ch + 256 * 32
    if (char == 'A') {
        irow = irow - 1
    }
    else if (char == 'B') {
        irow = irow + 1
    }
    else if (char == '3') {
        continue
    }
    else if (char == 'l') {
        itab = icol
    }
    else if (char == '&') {
        in = in + 1
        ch = menu(in); char = ch + 256 * 32

# If required, identify the third character
# in the escape sequence.
        if (char == 'a') {
            irow = 10 * (menu(in+1) - '0') +
                (menu(in+2) - '0')
            icol = 10 * (menu(in+4) - '0') +
                (menu(in+5) - '0')
            in = in + 6
        }
        else if (char == 'd') {
            in = in + 1
            ch = menu(in); char = ch + 256 * 32

# If required, identify the fourth character
# in the escape sequence.
            if (char == 'B' | char == 'J') {
                ienh = 4
            }
            else if (char == 'D') {
                icolul = icol
                irowul = irow
                iul = 1
            }
            else if (char == '@') {

```

```

ienhn = 0
if (iul != 0) {
    icule = icol - 1
    ixul = ix0 + (icolul * (iwidth +
        xspace))
    iyul = iy0 + (irowul * (ihigh +
        yspace)) + ihigh + uloff
    ixule = ix0 + (icule * (iwidth +
        xspace)) + iwidth
    iyule = ixul
    call vector(iunit,ixul,iyul,ixule,iyule)
    iul = 0
}
}
}
}
}
# If the character does not pass any of the above tests,
# it must be text. Load it into the text buffer. Return
# to the top of the loop and load the next character.

# For the first text character, flag the starting position
# of the text buffer by saving the current row and column.
else {
    if (ccnt == 1) {
        icoltx = icol
        irowtx = irow
    }
    text(ccnt) = char
    ccnt = ccnt + 1
    icol = icol + 1
}
}
stop
end

```



```

*****
#
# getgp -- routine to initialize the GP for gpmenu
#
# Calling arguments:
# none; the GP unit number will be read from the operator or
# a command file.
#
#####

function igetgp(idummy)

byte line(82)
integer gpldgo

call gtlin(line, 'Which GP are we using (1 or 2)?')
iunit = line(1) - '0'
if (iunit < 1 | iunit > 2)
%      stop 'Illegal GP unit number'
;

if (gpldgo(iunit) == 1)      # error
%      stop 'Could not initialize the GP'
;

igetgp = iunit

return
end

```

```

*****
#
# gtmenu -- routine to read a menu into memory
#
# This routine reads a menu file name from the operator (or from
# a command file) and reads the menu into memory.
#
# Calling arguments:
# menu (integer array(1020)): buffer for the menu read in
#
#####

subroutine gtmenu(menu)

integer menu(1020)

byte line(81)

call gtlin(line, 'Menu file name?')
if (line(1) == 0)
    call exit

%      open(UNIT=1, NAME=line, TYPE='OLD',
%      x      ACCESS='DIRECT',RECORDSIZE=128,MAXREC=6,READONLY)
%      ;

do i = 1,4 {
    k = 255 * (i-1) + 1
    l = k + 254
%      read(l~i+2) (menu(j),j=k,l)
%      }

close(UNIT=1)

return
end

```

```
#####
```

```
#
# putext -- routine to pass text buffer to the GP
#
# Calling arguments:
# iunit (integer): GP number
# nchar (integer): number of characters stored in the text buffer
# txtbuf      :
# ienh (integer) : specifies enhancement mode,
#                  0 = normal video, 1 = reverse video
# ix (integer): GP x co-ordinate to start printing text
# iy (integer): GP y co-ordinate to start printing text
#
#####
```

```
subroutine putext(iunit,nchar,txtbuf,ienh,ix,iy)
```

```
integer buffer (6)
      buffer(1) = 19
      buffer(2) = ix
      buffer(3) = iy
      buffer(4) = 2
      buffer(5) = ienh
      buffer(6) = 1
call gpque (iunit,6,buffer,0)

call gpque (iunit,2 + ((txtbuf(2)+1)/2),txtbuf,0)

call wait (iunit)

return

end
```

```

*****
#
# vector -- routine for GP underlining
#
# Calling arguments:
# iunit (integer): specifies GP unit number
# ix0 (integer): GP x co-ordinate to underline start point
# iy0 (integer): GP y co-ordinate of underline start point
# ix1 (integer): GP x co-ordinate of underline end point
# iy1 (integer): GP y co-ordinate of underline end point
#
#####

subroutine vector (iunit, ix0, iy0, ix1, iy1)

integer buffer (6)

      buffer(1) = 12
      buffer(2) = ix0
      buffer(3) = iy0
      buffer(4) = ix1
      buffer(5) = iy1
      buffer(6) = 1

call gpque (iunit, 6, buffer, 0)

call wait (iunit)

return

end

```

```

*****
#
# wait -- routine to
#
# Calling arguments:
# iunit (integer): specifies GP number
#
#####

subroutine wait (iunit)

common /gp1/junk(2),npend1
common /gp2/lunk(2),npend2

if (iunit == 1)
    while (npend1 != -1)
        ;
else
    while (npend2 != -1)
        ;
return
end

```

LIST OF REFERENCES

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